[ARTICLE 9.—EXTRACTED FROM THE BULLETIN OF THE U. S. FISH COMMISSION FOR 1891. Pages 357 to 406. Plates LXXV to LXXXVIII.]

REPORT

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EUROPEAN METHODS OF OYSTER-CULTURE,

BY

BASHFORD DEAN,
INSTRUCTOR IN BIOLOGY, COLUMBIA COLLEGE, NEW YORK.

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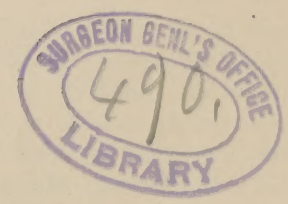

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9—REPORT ON THE EUROPEAN METHODS OF OYSTER-CULTURE.

BY BASHFORD DEAN,
Instructor in Biology, Columbia College, New York.

INTRODUCTION.

Oyster-culture as practiced in France has already been considered at some length in the publications of the U. S. Fish Commission,* most recently in a report by the writer,† summarizing the information obtained during the summer of 1891 in his visits to the centers of the industry in France. The present report, prepared under instructions from the U. S. Commissioner of Fish and Fisheries, Col. Marshall McDonald, is intended to complete a review of the European system of oyster-culture. The methods in use along the ocean coast of France are, in general, similar to those of the neighboring countries. It has, however, seemed important to understand the cultural modifications rendered necessary by changes in climate, shore characters, and saltness of water. Local conditions may not unnaturally have favored one particular locality to such a degree that methods of culture there in use might prove of little value in other and even neighboring regions. By general comparison a more distinct idea may be obtained of the actual character and extent of artificial culture. Thus may be seen by what manner and means one country of Europe has taken advantage of the practical successes of a neighboring one, has modified processes to suit local conditions, found by experiment to what limits imported methods might be carried, and succeeded or failed in securing the most judicious governmental aid in obtaining concession of cultural lands and in preserving the natural supplies of spawning oysters.

Of course, it is no easy matter to state all the reasons why, for example, if one system of obtaining seed oysters has succeeded most profitably in France, the same system should not have succeeded along the German coast or in England. But it is certainly reasonable to expect that by contrast and comparison of local characters, processes in use, governmental aids and restrictions in a number of countries, the general causes and general effects may, with the greatest probability, be induced. As to European legislative measures, a comparison, more or less general, has been attempted, and a few deductions which appear especially suggestive have been emphasized in the conclusion.

In the present discussion oyster-culture in the following countries will be considered: Italy, Spain and Portugal, Germany, Holland, Belgium, and England.

* U. S. F. C. Bull., 1890, list of references, p. 385–388, numbers 9*a*, 23*b*, 37, 47, 49*b*, 70*b*, 79, 82.
† U. S. F. C. Bull., 1890, p. 362–388.

OYSTER-CULTURE IN ITALY.

Modern oyster-culture seems to have been derived from Italy.* Before the visit of M. Coste to Lake Fusaro in 1853, but little had been done in France to regenerate an industry almost on the verge of extinction. The report of Coste pictured the successes of the cultural processes of Italy and strongly urged their introduction on the French coast, causing the institution, under the patronage of Napoleon III, of a series of experimental measures, out of whose successes and failures has grown one of the most important of the coast industries of France.

Especially interesting is the fact, already shown by Coste, on evidence furnished by pictured funeral vases, that the processes in use to-day at Tarente or in the lakes near Naples are apparently the very ones that the Romans employed as early as the time of Marius. The oyster stakes of the Lucrine Lake, we are told, represent in appearance and actual position the very ones that Pliny may have inquisitively examined, little thinking that their use would be handed down to posterity more carefully than the volumes of his lifelong work.

Everyone who has written of Roman oyster-culture has referred to Sergius Orator as the inventor of this branch of industry. It would seem, however, from evidence that has endured two thousand years, that this wealthy Roman represented little more than a successful culturist of his day, noteworthy, perhaps, because a patrician. His prominence, too, as a successful culturist has been accented by a remark of the orator Lucius Crassus, who, as his lawyer, defended him in a suit for trespass against the state in the matter of oyster property; his time-honored pleasantry that the question of a few feet of land made no difference to his client, who could, if necessary, raise oysters with success on the thatches of house tops, has given the grasping Sergius more credit than he perhaps deserves. Certainly the oysters from the Tarentine Gulf were very early known, and were by historic evidence planted, doubtless with method of culture, in the lakes near Naples. Tarente, as a Greek city of ancient wealth and commercial relations, is far more apt to have had oyster-culture than was Sergius to invent it.†

The modern industry is carried on extensively only at Tarente. It is here that the major portion of the seed oysters are produced which are afterwards cultivated in the bays and tidal ponds of the southern coast and supply the general market of Italy. The gulfs at the north do not appear to be favorable to the growth of the typical European oyster, *Ostrea edulis*. The Gulf of Genoa produces a small oyster, mainly for local consumption, *O. plicata* (more probably *Ostrea edulis* var. *plicata*), a species delicately flavored and appearing to find its best living conditions in waters as dense as 1.027 to 1.028. In the harbors of Trieste‡ and Venice another variety of oyster occurs, *O. edulis venetianæ*. This is generally regarded as poorer in quality than *edulis*, and its production, therefore, competes but little with the more southern industry.

Tarente (or Taranto) has been rich in its fisheries from the earliest times. Its shallow gulf, opening broadly to the Mediterranean on the southward, shelters its shore life, but readily renews its supply of water. At the head of the gulf, protected by prominent ridges, is the small deep-cut and almost landlocked bay that has for ages been

*As to the independent origin of the use of collectors in Connecticut, see Ingersoll, Oyster Industry, Tenth Census, 1884.

† For discussion of Roman oysters and oyster-culture, v. Philpots' "Oysters and all about them," Richardson, London, 1890.

‡ Soubeiran, Bul. Soc. d'Acclim., 2e série, VI, 105, 1870.

famous for its oysters—the Mare Piccolo. This is literally a small oyster-bearing sea, in every way comparable to the artificial one at the Sables d'Olonne. Its walls are its shelving sides, its floodgate is its constricted outlet into the gulf, one made still narrower by an outcropping island of rock—the ancient city and castle of Tarente. The Mare Piccolo is an oblong mass of water about 7 miles in major diameter, whose greatest depth is scarcely more than 40 feet. Its basin in general is saucer-shaped, with a bottom of firm calcareous sand, holding a depth of water especially favorable for purposes of cultivation, averaging perhaps from 3 to 4 fathoms. This remarkable shallowness tends not a little to maintain the water temperature, during the greater part of the year, warmer than that of the gulf beyond. The large surface for evaporation, in view of the small volume of water, would naturally lead one to expect an extreme density. As a matter of fact, however, this condition, which would undoubtedly be little favorable to the oysters' spawning, does not occur. The density of the water mass is, on the contrary, found to be uniformly low, as the fresh water entering the basin more than compensates for the loss caused by evaporation. A considerable part of this freshened water is derived from the small streams incurrent from the north. In this region, too, submarine springs are known to be present; of these the Citrello, which emerges near the Convent di Rosa, is especially remarkable.

The direct benefits of the tempering of water in these portions of the Mare Piccolo may be seen in the number of parks here. The specific gravity along this northern range of parks was found to vary (April 24, 1892) between 1.022 and 1.023 at 60° F.; to the southward and westward, about a mile distant from the outlet, the density had risen to 1.027 at 59° F.

As one approaches the city of Tarente on the railroad from Brindisi, a very good idea may be obtained of the extent of oyster-culture as the road bends around the shore of the Mare Piccolo. As far out as one can see the bay is bristling with oyster stakes whose ends project several feet above the surface. (Pl. LXXV, Fig. 1.) These are soon observed to pass into distant perspective in regular lines and to mark off the water surface into squares as of a checkerboard. These inclosures, which in France would be called oyster parks, measure about 15 feet square. They are leased at about 50 cents a year, and each culturist secures as many as he can cultivate. They are rented from a joint-stock company which has obtained from the city council the leasehold of the entire bay bottom, surveyed out in about twenty sections, for an annual sum of $10,000. The minuteness of the subdivision of this area is the result and also the cause of competition, and the energy of rival culturists adds much to the success of their industry.

The Italian is the very opposite of the French system of oyster-culture. French proprietors cultivate the shore lines between the levels of high and low water; their parks are embanked inclosures holding a few feet or inches of water until the tide advances; they cultivate their shores in a horizontal plane. The Italians cultivate oysters in all depths of water and make the number of oysters fattened in a given park stand in proportion to the volume of water. Having but scanty fall of tide, their system has become *vertical* oyster-culture. To cultivate horizontally the French have hardened their muddy beaches, have inclosed tidal areas, and have spread miles of flat cases of iron gauze to furnish growing space for their oysters. The Italian culturist has devised every means of supporting his oysters in the water volume between bottom and surface. In France, owing to unfavorable local conditions, the industry is minutely subdivided. A park of several hundred acres may be devoted to collecting

the seed oysters, a second park may be of value in growing the oysters, and a third may serve to fatten or prepare them for transport. A Tarentine park may represent every branch of the industry; in an area of 15 feet square a culturist may collect the young oysters, grow, fatten, and prepare them for the market.

The Italian process may best be understood by referring to the accompanying sketch (Fig. 1), which illustrates a Tarentine park. It consists roughly of corner posts, a web of ropes and various suspended devices for collecting oysters (A), growing (B), fattening and storing them (C).

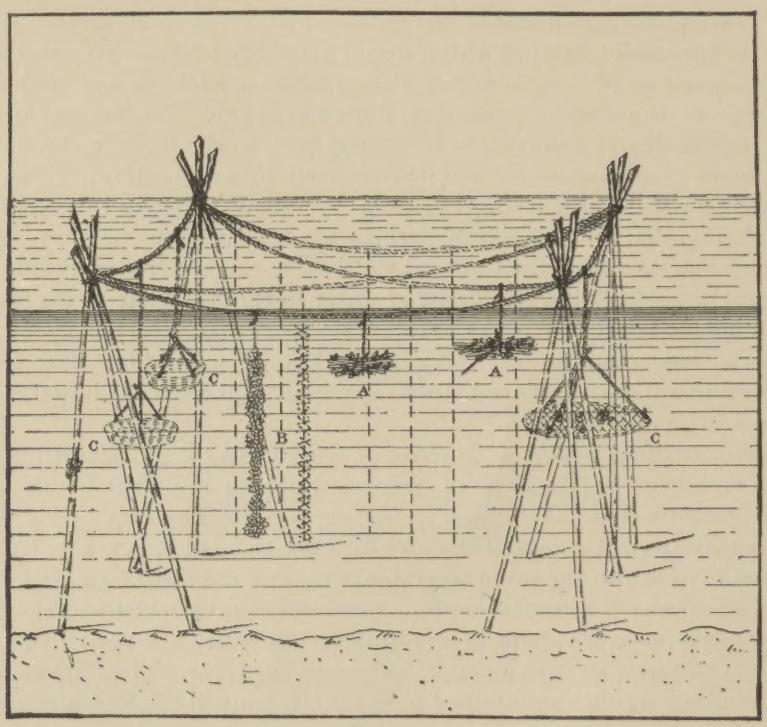

FIG. 1.

The corner posts, firmly implanted, mark the boundaries of the park. At each corner these are usually arranged in pairs, as seen in the figure, somewhat inclined toward each other and lashed together a few feet above the surface. Thus fixed they appear to be quite permanent, especially as their displacement by storm is not usual on account of the sheltered nature of the Mare Piccolo. The firm calcareous character of the bottom allows the posts to be readily inserted by blows of a heavy mallet. The posts themselves are of green pine, 6 or 8 inches in diameter, are not costly, and are apparently never tarred. The depth of the harbor allows their average length to be about 20 feet. In deeper water two or even three require to be spliced together, bringing, therefore, into culture a depth as great as 40 feet. The ropes forming a network between the corner posts must support the weight of the collecting devices (A and B). The cordage must therefore be strong and durable in water. A wire-grass rope an inch in diameter is manufactured in Naples for this purpose. It lasts for one or two seasons, and costs about one-half cent per yard.

The arrangement of rope may best be understood by referring to the accompanying diagram (Fig. 2). The supporting ropes are rarely exposed, except where attached to the corner posts. In the parks established in deeper water the matter of rope management becomes more complicated. The greater amount of rope required by the weight of the cultural apparatus has suggested an arrangement which both separates the cross ropes from each other and enables them to be more easily turned at the corners, as illustrated in the figure. With so light a scaffolding to support the devices for collecting and growing the young oysters, it is evident that the question of the weight of apparatus has been a very important one. For this reason, as well as on account of lack of tidal ground, the tile, as a device for collecting the young oysters, has been found unsuited. Wood, on the other hand, has advantages in point of lightness and cheapness. The loose bundles of hazel or gorse boughs, termed fascines (A, Fig. 1), become quickly water-soaked and form the most convenient collectors. These, when covered with young oysters, may be broken into twigs and woven into ropes, which, when suspended, utilize the water volume from surface to bottom (B). Oysters that have become detached and fallen to the bottom, together with grown oysters, may be placed for storage and final growth in the suspended baskets (C).

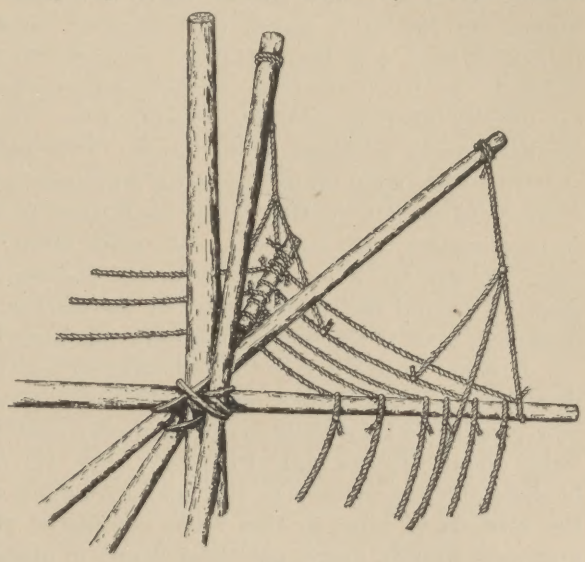

FIG. 2.

Thus outlined, the method of culture and its conditions may be more carefully examined. The supply of breeding oysters which furnish the spat is in any event a large one. The myriads of half-grown oysters lodged upon the suspended ropes spawn prolifically, and this supply is one that never decreases. A second source of spat is furnished by scattered oysters and beds of oysters that have either escaped the knowledge of the culturist or are difficult to secure. General dredging is but little practiced. The largest supply of scattered oysters is said to be in the immediate neighborhood of the parks where dredging is impracticable. It is certain that the spawning season in the warm waters of the Mediterranean is an extended one, stated by the proprietors to extend from April to October. The greatest set, however, occurs about the end of June. It was clear, however, from fascines that had been put down in January, and which were examined by the writer in April, that spawning had taken place during the colder weather, and it may in consequence be inferred that the spawning continues intermittently throughout the year. The development adventitiously of a portion of the generative product by lobes of testis or ovary has already been commented upon in the case of the American oysters along the southern coast of the United States.*

*U. S. F. C. Bull. 1890, p. 352.

The fascines, freshly prepared during the winter, are by degrees taken out during March, April, and May, and anchored in deeper water, often in clusters marked with buoys. In the early season the outgoing currents are said to be usually the most fruitful in spat, and the culturists arrange their fascines so that they may best be utilized. In May, when the spat is beginning to form in shallower water, the fascines are usually taken up, well rinsed, and, as they are now water-soaked, are suspended in the little parks as shown in the figure. It is here that the fascines get their second crusting with spat, often becoming whitened with accumulated oysters. They are allowed to remain in the better conditions for growth given by the shallower and warmer waters until late in the fall, more often until the following spring. By this time* the oysters have firmly attached themselves to the support, the shells often growing around the slender twigs of the fascine, so that they are apt to be naturally detached, even if the underlying bark has been loosened.

It is not until early in the following spring that the fascines are taken ashore and deposited in huge banks, as a preliminary to weaving the ropes. The attendants now proceed to take them apart, chopping each bough with its attached oysters into twigs about 8 inches long (Pl. LXXVI, Fig. 1). The oyster twigs are now deposited in baskets and are carried to the next attendant, who splices them ingeniously between the strands of rope, so that when completed the twist of the rope, together with increased weight, keeps the twigs firmly in place. Thus arranged, the rope bristles symmetrically with its oyster-bearing burden. Cargoes of these ropes are then rowed to the parks and put in place. The growing conditions of the oyster now become especially favorable. The heavily burdened ropes swing and vibrate in the currents, allowing each oyster to escape the accumulating sediment and to secure an equal share of the volume of floating food. Their growth is certainly rapid; an oyster three-fourths of an inch in diameter in March, when suspended to the rope, has attained by October about four times its original diameter, and has thus become marketable. Two years and a half, however, are generally allowed to produce an oyster of first grade in the Tarentine market.

Another advantage the culturists claim for the rope system of culture is the ease with which the entire product of a park can be overhauled, cleared of attached ascidians, mussels, and bryozoans, and, in general (the oysters being in plain sight), guarded from more dangerous enemies. It is evident that rope culture economizes space to a wonderful degree. A single rope 14 feet in length is said to rear about 2,000 marketable oysters. The baskets, seen in the sketch, p. 360, are an essential part of the Italian method of culture. In these, stray oysters collected from the bottom, as well as grown oysters taken from the ropes during the process of overhauling, are given their final growth. Storage is thus conveniently managed, the capacity of the baskets being more or less accurately known. The baskets vary considerably in shape and size, the most usual form being loosely woven and shaped like a cheese-box.

* The length of time that the collections are allowed to remain in position appears to be largely dependent upon the character of the season. The collectors from deeper water that have been rinsed and placed in the parks are often added to, if the season appears promising, by fresh fascines anchored in series and allowed to rise to within a yard or two from the surface. This degree of submergence appears to have been found most favorable for set. At this depth it is certain that the attendants can most readily give them the necessary care. They are clearly seen from above, are readily secured by a cross-barred staff, brought to the surface, rinsed of sediment, and replaced.

Another device used in giving the oysters their final growth is a net-covered iron ring, which, often having a large diameter (5 feet), may support four or five hundred oysters.

An important branch of the industry at Tarente consists in the export of seed oysters and of oysters of nearly marketable size which are intended for fattening in other localities, *e. g.*, Fusaro. Seed from half an inch to 1 inch in diameter sold during April, 1892, for about 30 cents per 1,000. The price of oysters two years old was then about 80 cents per 100. The average number of marketable oysters produced from each fascine is said to be about 500. The total production of the Tarentine industry can hardly be stated. An estimate based upon the production of four single parks would give the annual yield at about 20,000,000.

Compared with the industry at Tarente, oyster-culture in the historic parks near Naples is decidedly unimportant. A brief discussion of Fusaro and the Lucrine Lake should, however, be given as representing the best types of private industrial establishments and as illustrating the tidal pond culture of Italy. They are both within a few hours' drive from Naples, and are not over a couple of miles apart. Fusaro, the more northern, shelters under the promontory of Cumae, while Lucrinus, whose size was greatly reduced by the upheaval of Monte Nuova in 1538, is close to the Roman Baiæ. The entire region is one of great interest to strangers, and the inns in the neighborhood of the oyster parks owe not a little to those who evade Pozzuoli, hunt Roman villas, and are inclined to dine upon oysters, seriola, and falernian.

Fusaro, described by Coste in 1859, had its industry destroyed about ten years later, partly from volcanic causes and partly by lack of proper cultural care. Its decadence was caused, according to M. Bouchon-Brandely,* who visited Italy in 1879, (1) by the decomposition of organic accumulations which empoisoned the water; (2) by overcultivation of mussels; and (3) by excessive salinity of the water caused by the opening of the second outlet from the lake into the sea. Oyster-culture has, however, been successfully reinstated by Sr. Salvatore Milosa during the past decade. The present conditions of the lake and the methods pursued in its reëstablishment are therefore of interest.

Fusaro† is crescent-shaped, with canals communicating with the sea at either end. It is large, about 2 miles in circumference, but shallow, averaging perhaps about 4 feet. Near the southern end, where the large hotel or *Casino Reale* is built, the water is deeper, shelving at points to about 2 fathoms. A greater volume of water was secured by dredging out the accumulated sediments, and has proved one of the great causes of recurring success in oyster-culture. The former shallowness of the water allowed its temperature to become excessive. The same process of clearing the basin aided the good results obtained by improving the ingress of a small fresh-water stream at the lake's northern end. By this means it became possible to reduce the salinity of the entire water volume, a cultural advantage which was recognized even in the time of Pliny.‡ The water of Fusaro showed (May, 1892) a density § of 1.019 to 1.023, fresher than the neighboring sea by 5° to 9°. The temperature of a

* U. S. F. C. Bull. 1890, in reference list, No. 93, p. 48.

† U. S. F. C. Bull. 1890, in reference list, Nos. 9*b*, 23*b*, 42, 50. Also Issel, Ostricoltura, Genova, 1882; Philpots', l. c.; Aldieri, Dei Laghi Lucrino, Fusaro e Mare Morto, Napoli, 1879.

‡ Pliny (Bk. VI) records that oysters became larger and finer in the neighborhood of river mouths, and that they decrease in size and number in deeper sea water. There can be but little doubt that the value of Lucrinus was not a little dependent upon the less salty character of its water.

§ Sp. gr. at northern end of lake, generally, 1.021, 79° F.; at middle of lake, 1.021 to 1.025, 80°; at south bank, 1.019 to 1.021, 79° to 82°; sp. gr. of neighboring sea, 1.028, 78°.

shallow lake like Fusaro would, in a warm climate, tend to become excessive, but it may readily be tempered by admission of water from the sea gate. Warmth in general is not looked upon as a serious stumbling-block to culture;* freshened together with slightly warmer water is said, in these regions, to give the oyster its best conditions for rapid growth.

The industry at Fusaro is represented in the branches of seed collecting, oyster-growing, and fattening. The processes are practically those of Tarente. The water surface is broken with projecting stakes, especially numerous in the deeper part of the basin in the neighborhood of the pavilion (Pl. LXXV, Fig. 2). These are connected with a web of ropes supporting the fascines and baskets. About a thousand newly made fascines are annually brought into use and suspended in favorable spots for collecting, while those of the preceding year are removed and put in place in neighboring parts of the lake. The shallowness of the water renders unnecessary the weaving of the oyster-bearing ropes of Tarente. At points along the bottom may still be seen the little pyramids of stone recorded and figured by Coste. These do not appear to be regarded at the present day as valuable collectors. The management of Fusaro as a closed lake at the time of the spawning of the oyster has been only partly successful. The "mother oysters" are introduced in the early spring in the deeper water, but it has not apparently been possible to retain the spat-laden water in the sense that it had been retained at Brénéguy.† Higher temperature has doubtless its effect in rendering it necessary to renew the water frequently,‡ and during the latter part of May and the commencement of June, 1892, the water supply was renewed twice daily, allowing a large portion of the fry to escape. There can be little doubt that the problem in Fusaro is to study how long the water may be retained without endangering its oysters, the length of time appearing to be in direct proportion to the amount of collected spat. The surface area of Fusaro is not a small one, its depth is not great, and in favorable weather it would not be unreasonable to expect that natural aëration would allow the retention of the water for as long a time perhaps as several weeks. Further expriments in this direction appear to be needed.

The effects of seasons are extremely varying, and there can be little doubt that the time of fixation of the spat may, under the best conditions, prove as brief as several hours, although the idea given by Coste that the young tend to settle immediately in the neighborhood of the parent (*e. g.*, attaching to circumarranged stakes) was long since shown to be untenable. Spat-collection is extremely irregular in Fusaro and the Lucrine Lake, and if one is to be guided by the suspicions of rival proprietors, a large part of their industry consists simply in *élevage*, the seed being brought from Tarente.

The rearing of the oyster is conducted economically. The oyster is allowed to remain upon the fascine until it is almost of marketable size, the base of the shell often becoming not a little roughened by its long contact with the wood of the fascine.

In Pl. LXXVIII, Fig. 1, will be seen a rearranged fascine showing oysters of a second year's growth. Oysters that become attached are usually collected and put for final growth in suspended baskets similar to those of Tarente. The French *caisse* of wire gauze, which would seem of great advantage here, does not appear to be employed.

The Lucrine Lake, although smaller than Fusaro, is of great interest from a cultural standpoint. Its establishment is carefully organized and maintained; its sea wall forms the highway to Naples; its heavy floodgate renews the water through a

* Bouchon-Brandely, *loc. cit.*, p. 52, who records a temperature of 24° C.

† U. S. F. C. Bull., 1890, p. 372. ‡ Especially during the time of the dreaded hot winds.

massive sluiceway projecting into the sea. (Pl. LXXVII, Fig. 2.) The present establishment would rival in quality, if not in size, its predecessor, famous in imperial Rome. Monte Nuova, which sprang up in 1538, is supposed to have greatly reduced the extent of the lake and destroyed its ancient prosperity by volcanic ejections. Lucrinus is rich in its associations, and is even to-day in the possession of the family of Pollio, which has long held the property, and may represent the Roman Pollio, whose villa, with accompanying collections of ceramics and slave-fed *murænas* was undoubtedly in the immediate neighborhood.

Like Fusaro, Lucrinus has its waters perceptibly freshened, but its salinity can be better regulated. At one end of the lake a small canal leads a few hundred feet to a circular pond practically of fresh water, fed by bubbling hot springs (temperature as emerging, 104° F., sp. gr. 1.004); this is connected with a second basin of a bubbling spring (sp. gr. 1.010 at 90°) of slightly greater salinity. To these sources of freshened water should be added a deep spring in the neighborhood of the ateliers (Pl. LXXVII, Fig. 1). Lucrinus has but a single disadvantage in that its small size restricts its cultural limits, its extent being but about 10 acres. Proportionately its depth is greater than Fusaro, its basin shelving gradually to about 16 feet, and the bottom is less muddy, consisting mainly of tufa and sand. Its waters have a density of 1.0225 to 1.0245 at 79° to 80° F. Its temperature was the same as that of Fusaro, its greater depth and its constant communication with the outer water tending doubtless to maintain a greater uniformity in this respect. In the winter season the influence of the hot springs becomes of great service, favoring the growth both of the oyster and of its vegetable food. The proprietor of the lake, Cav. Domenico Pollio, favors the continuous introduction of sea water. The fall of tide (20 to 30 cm.) is sufficient to allow a proportion of water to pass out and to be replaced. This system has its effect doubtless in preventing the water volume from becoming either too fresh or too warm, and indeed the amount of the incurrent fresh water would render it decidedly dangerous to close the floodgates for any considerable time. It is, therefore, not remarkable that spat-collecting has never been permanently regulated. The yearly success has remained dependent upon favorable conditions of season, *i. e.*, a season producing a sudden and complete spawning, shortening the embryo's swimming stage, and reducing thereby the chances of the escape of the fry through the sluiceway.*

Culture is carried on by the usual method. The stakes, seen in Pl. LXXVII, Fig. 1, support a meshwork of ropes bearing fascines and baskets. Collectors of all varieties are brought into play, bunches of tiles roughly fastened together, and flat stones even being often included. *Élerage* is doubtless the cultural strength of Lucrinus, and the flattened wickerwork trays filled with half and full grown oysters are suspended at every possible point of support. The growth appears to be phenomenally rapid; a second year is said to be sufficient to produce an oyster 3½ inches in diameter. The Genoese oyster (*O. plicata*) is occasionally produced, being known here as the *Ostra reale*, and is exquisite in color and flavor. Other shellfish are naturally abundant in the basin, the *vongola* (*Tapes*) being of especial commercial value. The fish supply entering daily from the sluiceway during the falling tide is often of considerable value. The seriola, suggestive of Roman dinners, is especially abundant here. The straw runway which allows fish to enter and not to escape, will be noticed in Pl. LXXVII, Fig. 1, photographed from the bridge over the sluiceway.

* Granting that an embryo would have a greater chance of escape in 48 hours than in 4 hours.

Before passing from Italy mention should be made of the oyster park in Naples near the Castello del Ovo, and the Santa Luccia. The former, checquered off with stakes and ropes, suggests a diminutive Tarente. Neapolitan oysters, however, have been brought to thrive where the water is not of the purest, and are therefore regarded with suspicion. Several cases of typhoid fever are recorded that appear to have been traced to this source.

OYSTER-CULTURE IN SPAIN AND PORTUGAL.

Two difficulties have stood in the way of developing oyster-culture in Spain. An extended seacoast has allowed local demand to be satisfied without recourse to artificial methods, and inconveniences in the matter of transportation into the interior of the country have prevented or retarded the development of regions where culture would naturally have become profitable. There is little in the way of technical devices to be learned from the study of the Spanish oyster-production, and in the present connection it will be of little value to discuss the matter at length. The chief localities which carry on production for the market of Madrid are Santander and Coruña. Both are on the northern coast, the latter near the northeastern part of the peninsula in the region of Cape Finisterre. At these points oyster-culture has been introduced after the French method.

The oyster industry in Spain is undergoing the same evolution that it has had in France. The northern coast, in its deep-cut and rock-built bays, has provided shelter for a large number of small, but very rich natural oyster banks. Such, for example, was that of San Nicolas de Neda, about 20 miles from Coruña, which was recorded in 1870 as having an extent of 2 square miles, or that of San Martin de Noya, 50 miles from Coruña, smaller, but exceedingly rich. These have been little protected by legislative measures and have been ruthlessly dredged, even by those who should have been their guardians. Their condition has finally become such that the market price of the oyster has become high enough (advancing within twenty years from 2 cents to $2 per 100) to insure the profitableness of artificial culture. The only reason, it is said, why the natural banks have not been entirely exterminated has been the rocky nature of the bays, which has hindered dredging. The demand for oysters in the French ports seems to have been the first incentive to overdredging.

The present need of Spanish oyster-culture is that of quick and low-priced transportation, which will place fresh oysters in the city markets at a not unreasonable price. By this means artificial culture will become more profitable. Spain is not wanting in industrial establishments. One, for example, in the bay of Lloregat, is well appointed and of considerable interest; unique, certainly, in making use of a windmill to renew the water of its high ponds. At Santander there is an establishment of the type of Arcachon, where case culture is carried on; in a sheltered part of the harbor the cases are arranged in rows and are rarely exposed, even at low tide; inclosures are not employed, and the cases are stout in build, supported about a yard from the bottom; growth is said to be exceptionally rapid and the oysters are usually marketed at the end of the second season. A similar establishment, about 20 miles to the eastward, has been quite successful in production. The intense saltness of the water,* sp. gr. 1.027 to 1.028 (68° F.), doubtless tends to render general production unprofitable, and the absence of thrifty beds of spawning oysters in the neighborhood

* U. S. F. C. Bulletin, 1890, p. 384.

can not fail to have a similar effect. Seed oysters are accordingly imported, mainly from Arcachon, on account of cheapness.

Efforts to regulate the banks after the method of M. Coste were recommended and experimented upon by M. Graells,* by royal commission, unsuccessfully.

In the markets of Lisbon the only obtainable oyster is the species known generally as the Portuguese (*Ostrea angulata*). This species, introduced into France a quarter of a century ago and a little later into England, has proven of great commercial importance. It is hardy, prolific, and rapid in growth, and in cheapness of production it makes undoubted amends for its poorness in quality.† As this species has long been known to be related to the American oyster in sex character, it has seemed of interest to ascertain its native living conditions and to what degree it has been locally cultivated. The Portuguese oyster is described as occurring in river mouths along the west coast of the Spanish peninsula. It appears to attain its best conditions along the southern coast of Portugal, but may be studied not unfavorably near Lisbon in the widened mouth of the Tagus.

The harbor of Lisbon is a miniature sea, a mile or more in width and half a dozen miles long, its entrance being formed by a narrows a third of a mile wide and 2 miles long. The southern shore of this sea, opposite the city, is the home of the oyster; it has shallow water, curving beaches, and incurrent freshened streams. It commences at the narrows opposite the city markets, Cacilhas, sweeps southward, then eastward, then northward, where the river begins to take upon it the tawny color of the "*mer de paille.*" It would naturally seem from the constricted mouth of the river that the water of the harbor would be considerably freshened, as it doubtless is at certain seasons, but the included water volume is so great and the sea inlet so deep that the incurrent fresh water is not apparently felt within 10 miles of the coast. Eight miles from the mouth of the Tagus the density, on October 1 to 3, 1891, continued as high as 1.0235, at 67° F, while the bulk of the water appears to average 1.0245 to 1.025 (67° F). At the Lisbon custom-house, in the current of the narrows, the density reaches 1.0264 (67° F). A gravelly shoal extends from Cacilhas, fringes the southern shore, and furnishes the site of a natural oyster bed, very favorably conditioned. The water is here shallow for a quarter of a mile off shore; the bottom is a compact crust of sand, gravel, and tawny mud, though it is often exceedingly soft below; it is usually densely carpeted with a fine ulva, not enough to stifle the oyster growth and perhaps contributing to its support as a purveyor of oyster food.

From time immemorial the region has been rich in oyster production, and for years has not merely furnished the Lisbon market, but has been the center of active export. The original cargo that gave accidental origin to the French-Portuguese oyster was taken from this neighborhood. The ease with which the *angulata* could be collected, its cheapness and hardiness during transport, have for a long time made its export considerable. An English company a dozen years ago secured a fishery franchise and supplied the English market with Anglo-Portuguese oysters, shipping them in great quantity to the grounds of the Thames estuary and there fattening them for several months. This export was continued until the company became

* U. S. F. C. Bulletin, 1890, reference list, pp. 385–388, Nos. 42 *a* and *b*, 12*c*, p. 200; also Francisco Garcia Sola, Fisheries of Spain, Int. Fish. Exhibition, London, 1883; extract in Philpots', p. 693; D. F. Balaguer y Primo, Cria de los Peces, de Guesta, Madrid, 1878, pp. 47 *et seq.*

† U. S. F. C. Bull., 1890, p. 366; also in reference list, pp. 385–388, Nos. 7 *d*, 9 *c*, *d*, *e*, *f*, 12, 14, 37, 39, 51, 63 *a*, *b*, *c*, 82.

exceedingly prosperous and was, by the influence of rival merchants, deprived of its franchise. Portuguese companies have since had control of the natural ground and from lack of financial support have, for the past few years, been unable to promote the industry. The crisis in the financial condition of the Portuguese government has been in great measure responsible for this decadence, since money is readily invested at higher rates and with more speedy profits than in oyster-culture.

Portuguese cultural methods have always been primitive. Cheapness of product has as yet forbidden the introduction of artificial methods of collecting the young. The spat occurs naturally and in great quantities throughout the shallow water, attaching regularly to gravel, stones, shells, and even to seaweeds, in a way quite unlike that of the more delicate French oyster. The spat growing rapidly is, after several months, collected, together with its abundant "cultch," roughly sorted over, and sold in baskets as seed for distribution in the tracts of foreshore held in stated rental by fishermen. Culture, therefore, like our own, takes place in waters where the oysters are not seen and in general little attended to. The mean depth of water in culture is about 2 fathoms. The rise and fall of the tide (which becomes as great as 17 feet at lunar tides, averaging about 8 feet) is taken advantage of in the process of collecting the oysters, which is done altogether by hand, as far as the writer could ascertain. In the majority of instances the oysters after being raked are cleaned and taken to the market at Lisbon, where wholesale dealers arrange shipments for export. Locally, as in the United States, oysters are sold either in the shell or removed from it by bulk in fluid measure. The former are sold throughout Lisbon by itinerant venders, most picturesque and characteristic street types, tall, bronzed, bare-legged fishermen, whose cap with tasseled end hangs down at the side of the head, shouldering a stout pole with dependent salver-like baskets. The shell-less oysters are sold more cheaply, the price averaging about 2 cents per dozen. Oysters are not highly esteemed in Portugal and their use is said to be confined mainly to the lower classes. Like the American and unlike the French oysters they are not infrequently given over to cooking.

The living conditions of the Portuguese oysters have in part been already given. The water is slightly fresher* than the normal in the French localities, though by no means as fresh as that of American oyster-bearing waters. The favorable character of the bottom and the general absence of oyster enemies have allowed the culturist to scatter the oysters broadcast, without the expense of the wire-gauze cases, which have proven so necessary a part of the French industry. Some of the Portuguese conditions are curiously similar to those of the "raccoon" oysters of the southern Atlantic coast of the United States. The marginal oysters are not infrequently exposed to the air and sun heat, and the clustered condition is a usual one. This, as in South Carolina, has been largely the result of the muddy and unstable character of the marginal foreshore. The gravel and sand do not appear to be sufficiently consistent to fix the oysters firmly, and accordingly these appear to cluster in clumps of as many as thirty or more individuals. This cluster is apt to gain stability, its weight driving the undermost oyster as a wedge into the softer mud and firmly fixing it; shiftings of bottom and accumulations of gravel are both serviceable in banking around the implanted cluster and rendering its uprootment still more difficult. The individual oysters are, in addition, suited to their surroundings, often becoming, on

*U. S. F. C. Bull., 1890, p. 366.

account of their crowded situation, fingerlike in shape, with a narrow, knifelike projecting margin. A further advantage gained by clustering is doubtless that of better feeding conditions, not merely in being raised from the stifling seaweeds, but as less disturbed by bottom sediment stirred up by storms.

There can be little doubt that the Tagus, if undisturbed, would produce raccoon reefs as remarkable in many regards as those of May River, South Carolina. The comparison with raccoon oysters might even be continued further than in the irregular shape of shell, in its often thin, watery, and tasteless character caused by its exposed position. The color of the flesh, however, is not that of the southern oyster; it is an opaque blue white, often dark slaty, the fringing edge of the mantle, as already noted, being broad and jet black, the sense papillæ long and coarse.

It seems extremely significant that these two oysters, the Portuguese* and the Virginian in its raccoon variety, become remarkably similar when their physical conditions are paralleled. It is likewise noteworthy that the same natural method of culture, transplanting seed from shallow into deeper water, becomes also paralleled. There is apparently less difference between the typical raccoon and the northern oyster of the American coast than between the raccoon and the *angulata* of Portugal. The taste, the peculiar slaty tint, and broad sensory mantle rim of the Portuguese oyster are not discriminative. These characters appear to become acquired by the American species when introduced into European waters. The original quality of the American oyster appears to deteriorate steadily from the time of its introduction, and this species thus often attains a well-earned reputation for inferiority. The greater saltness of the European localities has been noted as one of the conditions that have rendered unsuccessful the introduction of the American oyster, and it certainly has an effect in checking the spawning habits, for in no instance has a well-authenticated successful spawning been noted in England, France, or the Netherlands. Where the American oyster has been introduced it has invariably lived, but has not succeeded in regaining its original quality. Where the density has been as low as 1.023 to 1.024, it has gained in flesh, but has become (*e. g.*, Arcachon, Jerseke, and Whitstable) of the opaque, clayey, Portuguese type, rivaling the Portuguese oyster in its peculiar taste.

The *angulata*, moreover, like the raccoon, when given the better conditions of deeper water feeding, and when transplanted in cultural processes, as at Arcachon, develops, as might naturally be expected, a long, regular, and well-shaped shell, almost losing its marginal, involuted angularity. The raccoon oyster becomes by cultivation creamy white, with a flavor not unlike the Whitstable *native*, but the *angulata* assumes its slaty color and coarseness in texture and taste that have very naturally rendered it of inferior commercial value. On this account it is not the most thankful task to compare the Portuguese to the American oyster—to suggest, in fact, that it is but a variety of the Virginian species. But it is not improbable, everything considered, that the *angulata* (derived perhaps at no remote age from the more generalized variety-forming American species), has been produced through the local agencies of feeding conditions and increased water density. It reverts most clearly to the American species through the raccoon variety, its plicated shell rim being not more than a variation of that of the less plicated raccoon. Shell plication, which has been made of such value in specific discrimination, can hardly be given great weight after its variation in this regard has been examined under natural con-

* Cf. Winslow, as to similarity in sex character and development, Rep. Com. of Fish. Md., 1881, p. 68; for *edulis* should be read *angulata*.

ditions. For it may be found that (1) many shells are, if anything, less plicate than in some types of raccoons; (2) the plication may increase in number from three, angularly marked, to a dozen or more, faintly suggested; (3) the younger oysters are often comparatively smooth in shell characters.

The oyster industry in Portugal is remarkable, inasmuch as it is prosperous although practically unprotected by law. Oysters are abundant and low in price, a result, however, which could never have been obtained had the demand been great enough to render it profitable to introduce improved dredging apparatus, with perhaps a consequent industry of canning. No canning factory, it is said, exists in Portugal. Lack of demand has also tended to deter innovations in culture.

OYSTER-CULTURE IN GERMANY.

In Germany, oyster-grounds exist in only a single district, the sheltered corner of the North Sea, where the coast line has almost reached the frontier of Denmark. As this area of natural production is a very restricted one, it may reasonably be inferred that it possesses exceptional characters and conditions which render impracticable the introduction of the French system of oyster-culture. Such a conclusion has been firmly maintained by Prof. Möbius, who, as the state authority in these matters, studied the conditions of the industry when the question of replenishment of the oyster banks was being agitated. His chief works, Ueber Austern- und Miesmuschelzucht (1870), Die Auster und die Austernwirthshaft (1877),* have become classic in the literature of oyster-culture. If his conclusions be altogether accepted, a number of corollaries to his proposition seem too important to be allowed to remain undiscussed. Thus, for example, it would follow that the success of the Dutch and French industries was dependent on exceptionally favorable local conditions, and that, therefore, the introduction of artificial methods into a foreign country might not succeed even when large natural oyster-grounds were in the immediate neighborhood, for it is to be remembered that the natural banks of Germany are the largest in associated series, if not the most productive, in all Europe.

As to the conditions of the oyster banks:† They occur, as has been noted, in but a single district, a corner of the North Sea which has been cut off and sheltered by a barrier of fringing islands. This included area is about 50 miles long and about 15 miles wide, extending due southward from the Danish frontier to beyond the line of the ancient town of Husum. Its sea wall, protecting not a little the low-lying coast of Schleswig-Holstein from the storms of the North Sea, is formed principally of the three long, fringing islands, Röm, Sylt, and Amrum, in whose immediate lee occur the largest and most fertile of the oyster banks. The tranquil conditions which this considerable water area offered, with bays and sheltered coves, seem to have been from the earliest times not unfavorable to oyster growth; but doubtless its limits have been shifting and changing, tending to increase shallowness and to reduce the extent and sweep of its currents, and perhaps to make it less and less of an oyster sea. Its waters are not deep, the fall of tide averaging perhaps about 10 feet, at lunar tides becoming as great as 18 or 20 feet, and exposing hard sandy flats over the greater portion of its area. These have given rise to the name *Wattenmeer* (sea of flats or shoals). The flats occur largely on the side of the mainland, and the outrunning water, having to

* Wiegandt und Hempel, Berlin, the latter translated in U. S. F. C. Rep., 1880, p. 83.

† Cf. Möbius, Die Auster und die Austernwirthschaft, 1.

pass from the higher table-lands to the deeper North Sea, has cut wide and often deep channels bending between the islands. In all of these deeper areas are found oyster banks, sheltered as far as possible in the lee of seaward islands. Here the depth, normally between 10 and 30 feet, is sufficient to keep them covered with water even at the lowest spring tides.

The location of oyster banks does not appear to be always, as figured by Möbius (Die Auster und die Austernwirthschaft, p. 5), on the steep-sloping side of a channel, but seems to be in every way similar in position to those examined by the writer at Cancale, Auray, and Arcachon, the banks being, in many instances, situated in the widened channel, often upon slightly elevated areas, the irregular limits of which can be determined by the sounding pole. The bottom, especially in the northern portion of the Wattenmeer, is firm and stable, a mixture of sand, clay, and mud, and that it is in the main favorable for oyster growth is seen in the lines of natural oyster banks which form almost a diagram of the deeper waters. At points, however, as in the channels of Amrum and throughout the southernmost parts, muddy areas occur; these are soft, often shifting, and are naturally unproductive. The flats have exceptionally shifting sands; they are in general hard and firm, readily sustaining the weight of a horse and cart. The rapidity with which the rise and fall of tide cover and uncover the extensive flats has been emphasized by Möbius as one of the unfavorable conditions of the region, causing harmful accumulations of sediment and general shifting of sand and mud. On the other hand, it can hardly be doubted that the sediments continually deposited from the landward shore, *e. g.*, from the Husum River, would accumulate very seriously but for these currents. Where the outgoing currents are the strongest there apparently exist the most favorable conditions of bottom for the location of oyster banks, as Möbius has noted.

The water conditions of the Wattenmeer are directly comparable to those of Arcachon in point of saltness, the normal density being about 1.024; this degree has already been noted as possessed by the chief centers of oyster-culture in France* and in Italy, especially in regions that have proven favorable for production, *e. g.*, Auray, Arcachon, and Tarente. A table of densities prepared by the writer during his visit to the Wattenmeer shows, moreover, that the waters from Sylt down almost to the mouth of the Husum canal vary surprisingly little in density, even at different tides, the temperatures remaining almost uniform. This uniformity in the water density was not expected in view of the rapid filling and emptying of the basin, and is somewhat difficult to account for, suggesting a surprising regularity in the incoming volumes of freshened and salt water. It is noteworthy, perhaps, that the small freshened streams that contribute to reduce the density of the entire water volume appear to be distributed very evenly along the landward margin.

The oyster banks number about fifty. Their length varies from a few hundred feet to a mile and a half, while the breadth averages hardly more than a few hundred feet. The exact position of each is accurately known by means of ranging sights, and the government, as will later be noted, examines their condition yearly and determines which are sufficiently rich to be dredged from.

We may next briefly examine the way in which the oyster banks of the Wattenmeer have been managed. They have certainly been retained in productive condition

* See table of densities in U. S. F. C. Bulletin, 1890, p. 384. The densities were taken at about the same season of the year. The total difference in densities at various stations in the Wattenmeer during different tides (48 hours) is not greater than sp. gr. 0.001.

at a time when those of other countries have been destroyed. The policy in their administration has been eminently conservative, aiming (1) to preserve the banks rigidly, to guard the terms of leasehold against overdredging, and (2) to favor in every way maximum productivity in natural areas, rather than to experiment in lines of artificial culture or to allow the tidal lands to be held in favorable leasehold for this purpose.

Historically the banks have been, for three centuries, the property of the Crown. The Danish Cronicle, published in Husum in 1652, shows that even at that early date their positions had been determined, and they seem to have been surprisingly similar to those of to-day. Under the late Danish rule the management of this domain was a lenient and apparently a prosperous one, probably in part because unaffected by railroad transportation. The last company under this régime, a Flensburg firm, is said to have rented the fishing franchise for an annual payment of $17,000, and to have been allowed to fish unrestrictedly. The company, strange to say, conservative in its management, feared to injure the prosperity of the grounds and allowed only a stated annual amount to be dredged. When the property was transferred to the German Empire about 1866, the dredging franchise passed into other hands, and again in 1879 the Prussian administration caused changes to be made in the holding, as well as in the terms of the lease of the fishery, bringing the details of management more than ever under the direction of the state. A reservoir with buildings intended for storage and fattening of oysters, located at the mouth of the Husum Canal, which had been constructed by and formed the headquarters of the former lessees, was now purchased by the government and became a supervising station. A guard or inspector was to be stationed here, under direct supervision of the Baurath at Husum, and two patrol sailing vessels and a small government steamer were to make their headquarters in the neighborhood. The arrangement of this reservoir station is an interesting one and will be discussed later.

The leasehold now to be granted was carefully devised to prevent overfishing of the banks, requiring (among other stipulations, which are hereafter given) that each bank be yearly examined by a committee which should include a government authority, in this case the Baurath at Husum. No more than the exact number of oysters thus designated should, under heavy penalties, be taken; all oysters should be brought to the government station at Husum to be counted, and to insure that no undersized oysters had been removed. The lessees, having the exclusive right of fisheries, were to pay the government a percentage on the total number of oysters allowed to be taken. Under the stricter terms, the leaseholder (for twelve years), after two years' exploitation, declared that the industry was profitless, that the banks were deteriorating and that he wished to cancel his lease. To this, however, the authorities would not consent, but a compromise, aiming to regulate the banks, established a complete close season for ten years (expiring 1891) and allowed the lease to continue from the end of this period. The lessee seems to be little more than a fishery contractor of the government, and it is not surprising that in his management he has resorted to similar contracting methods. He thus contracts to pay the dredging vessels, about ten of which are usually employed, a percentage upon their catch—a price averaging about $4 per ton (700 to 800 oysters). The catch is paid for when delivered at the station at Husum. The governmental tax of about $14 per ton (up to 3,000 tons) is now imposed, and the lessee must pay the freightage to the railroad station at Husum,

which again by contract adds nearly $1 to the price per ton of the oysters. The lessee has finally full liberty as to the selling, the market price being more or less determined by the price and duty of the Dutch and English oysters. The price at the Husum station varies between $3 and $4 per 100 oysters.

From a practical standpoint it is to be noted that on the governmental side in this system of leasing oyster property the state is assured that the natural grounds shall not be destroyed and that the single contractor is thus made directly answerable for excesses. On the other hand, it would be seriously questioned by the French or Dutch culturist whether this monopoly in management would be most profitable in the end. It certainly does not tend to reduce the price of oysters, because it does not favor the granting to individuals of concessions for cultural purposes near the natural oyster banks. It is certainly the antithesis of the open competition in oyster-culture which has furnished the coasts of France and Holland with one of their most prosperous industries. The French reserve the natural banks merely as a source of seed oysters artificially collected in the neighborhood. The German industry exists solely upon the annual surplus of its natural supplies.

The question why the same system of culture which has proven so successful in France should not have been successfully introduced in the Wattenmeer is thus important both as a biological consideration and a matter of governmental policy. Prof. Möbius, after a consideration of the matter, has urged the following reasons why all efforts to extend oyster-producing areas and to introduce artificial culture would be lacking in practical success. He states in summary that the unstable character of the bottom of the Wattenmeer, together with the sediment-bearing water, is the most adverse condition. This restricts the natural limits of the oyster-bearing areas, causing any increments to be temporary at the best, and renders it impracticable, from the point of expense, to solidify areas for the extension of the natural banks. His second reason is that the biological conditions of the Wattenmeer are so exactly poised that the oyster supply can not be permanently and largely increased, mainly on account of failure in quantity of oyster food. And third, the reason which is indorsed by Dr. Hoek, that the coldness of the northern winter, together with the remarkable storm tides, renders cultivation impracticable.

As far as the silt-bearing character of the water and the muddiness of locality are concerned, it is certainly of interest to note to what a remarkable degree these natural difficulties have been overcome by French culturists during the past decade. Production as well as *élevage* is brought to yield practical results in localities which were recently thought to be less than valueless, where neighboring oyster beds not merely did not increase, but were able to exist only by vigorous culture. Even in regions most favorable for production the adverse condition of muddy shore lines is not infrequent, and appears in fact to be far more general than in the neighborhood of the islands Sylt, Amrum, Röm, or Föhr. Prof. Möbius has already commented upon the muddy character of the Arcachon basin.* In the Auray region, in the neighborhood of the natural banks, a large part of the tidal shore has so little consistency that

* Ueber Austern- und Miesmuschelzucht, 9–12. The discussion here given of the natural conditions of Arcachon leads one to expect anything but the development of a prosperous industry. We learn, for example, that "die grossen Erwartungen, mit welchen die künstliche Austernzucht im Bassin von Arcachon in Angriff genommen wurde, sind leider nicht erfüllt worden. In Bordeaux hörte ich aus zuverlässigen Munde, dass viel Geld dabei verloren worden sei."

if tiles were placed there they would be instantly engulfed. These localities have, however, been reclaimed by a more or less recent process which forms a surface crust, macadam like, to give a suitable support for the collectors and their manipulators. This process, as at Kergurionné, though costly, has proven of practical value, as can be inferred from the extensive continuance of the practice. The very general use of the champignon collectors in the Auray (Morbihan) region is alone significant of the muddy character of the water, which renders of the utmost importance the question of determining the exact time to put the collectors in place. In fact in all of the French regions of production silt deposit goes on so rapidly that the tile when in position is said to retain its value but little longer than a week; it is to be noted that even during this short time its upper surface has become unproductive and that the undermost tiles in many of the forms of collectors are very slightly, if at all, spat-bearing.

Möbius maintains that the size of the banks in a given region can not be materially augmented—a matter which is of great interest even from the standpoint of pure biology. Not that it is at all to be questioned that a natural bank would under normal conditions remain more or less uniform in size and in the proportion of its component organisms—but it is the theory involved in this question that seems to the writer susceptible of broader interpretation than has been assigned it. *Biocœnosis* is the term applied by Möbius to express the mutual interdependence of species existing in a colony—a condition of happy-family existence in a natural cage whose limited food supply locks up the chances of permanent numerical increase. In accordance with this keenly poised life-balance Möbius infers that the banks of the Wattenmeer can not be permanently added to, even by artificial means (Auster u. Austernwirthschaft, p. 78). He notes, for example, that a season favorable to oysters, will, *per se*, cause the oysters during the following seasons to fall back to their normal, inasmuch as food material has thus been prepared for the enemies (crab and starfish) whose increased progeny will restore the balance of life.

The important inferences drawn from this doctrine of life-balance, do not, however, seem to be entirely warranted by the premises. We are led, for example, to infer that individuals are dependent upon the colony, and that the colony holds the curb, checking the permanent increase of one form at the expense of another. On the other hand, struggle for survival is undoubtedly the democracy of animal living, and in these days it has been pretty clearly established that the colony is but an incident more or less transient in the survival of the fittest. So the biocœnose, as we must accordingly admit, becomes but an episode in colonial life, whose duration depends upon the enduring force of its component species, where quickly moving predatory forms have the right of might, where stationary and defenseless forms have become mimics to escape their enemies, or have developed a surprising fecundity to survive the dangers of a compressed living-area or unfavorable environment. It can not at present be doubted that the scale of the struggle may readily be turned in favor of but a single type or species. Artificial devices may thus become the rapid undoing of the slowly struggling biocœnose, for they favor the protected species and would not unreasonably tend to blot out the accompanying enemies of this form.

Thus, in theory, an oyster protected from crab and starfish by a raised gauze-covered case gets thrifty feeding conditions without danger of becoming engulfed by mud or sand. The amount of spawn produced by the oyster thus favorably reared becomes increased, a far larger proportion of the young are secured by the artificial devices, and this progeny is so situated that their natural enemies may be watched and destroyed. Conversely, the enemies, thus artificially circumvented, find less nourishment, spawn less prolifically, and run continued danger of destruction from the traps of culturists. These results destructive of the biocœnose would none the less happen, be it understood, granting that the food quantum, as Möbius states, is an altogether limited one. But in the case of oysters living in what is practically an open sea, the food supply does not appear to be of the strictly limited character that Möbius has assumed. And his illustration of the carp in a small pond producing no more than a definite weight in annual yield, does not seem to be absolutely pertinent. Nor would the comparison be closely applicable even if the number of carp were supposed to be taken from the pond and set free in an open river. Their yield in weight would doubtless be greater, but even then fish food is not to be compared either in quantity or in capacity for exhaustion with the minute oyster food plant-life which is continually transferred through a limitless volume of sea water. The boundaries of a natural bank are certainly not fixed by food quantum. The food stuff may, it is true, vary in quantity in different regions during the same season, or in the one locality at different stations, seasons, or even tides.* But there seems in general to exist a food normal which is recognized as characteristic of a locality.

Aside, however, from this question of local variation, the amount of food that is actually brought to an oyster colony seems to the writer to be in direct proportion to the volume of water passing over it. If this volume be infinite, as it is in the Wattenmeer, exhaustion of food supply would seem an impossible condition. Barrenness and sterility of water could not occur; general transfusion of floating or of free-swimming micro-organisms is very clearly one of the characters of the open sea. The lower water layers that may have been screened out by a thrifty oyster bank would not remain without organisms, but would immediately be replenished from above by the currents that exhausted the lower layers. The writer had this impressed upon him in its practical aspect while examining the various cultural establishments of the French, Dutch, and Belgian coasts. The test in these instances seems a fairer one, since the side-dependent questions of sediment accumulation and danger from enemies is excluded by the cultural device of wire-gauze cases.

In a situation where the water volume becomes an extraordinary one, myriads of oysters are cultivated. At points where this water volume is increased by currents the cultural possibilities are found to become almost limitless. At Ossegor, for example, near the lower end of the lake, where the water is constantly changing, the cases were arranged in continuous lines, utilizing every available point,† each case containing about a thousand oysters, so tightly packed edgewise that it would seem almost

* Cf. however, New York State Report of Oyster Investigation, 1886, p. 72 *et seq.*; U. S. F. C. Bulletin, 1890, 344–349.

† U. S. F. C. Bull., 1890, 375, Pl. LXXIV, Fig. 2.

impossible for them to open; yet growth and fattening under these conditions was in every way noteworthy. In localities where the proportion of normal food organisms is naturally high, a greater quantity of oysters can be raised in a given water volume, *e. g.*, Soudre, Whitstable, Ostend. In such localities the naturally high food normal may be artificially increased by conditions of *claire* culture, where a given volume of water is retained in ponds and given the best conditions for rapid increase of diatom life. Warmth, richness in plant food (Marennes), and a proper degree of salinity may give the forcing conditions of what might be likened to greenhouse culture. In some instances a remarkable number of oysters may be fattened in a fixed bulk of water. At La Tremblade so favorable are the conditions that in the shallow *claires* (whose water is renewed but once a fortnight, and whose depth averages less than a foot) fifty oysters are normally fattened to the square yard of bottom.

In regions where the waters do not contain a high percentage of food organisms, culture in closed ponds is clearly unprofitable, as the water is both low in food normal and limited in volume. In instances of this kind it is understood that the two essential conditions, degree of temperature and salinity, have remained practically comparable; otherwise it is evident that from these causes, as much as from actual lack of food, the oysters may be restricted in growth. The instance that Möbius cites, that of the oyster reservoir at Hayling Island, as demonstrating that the oysters had exhausted the food supply and remained dwarfed in size, may, judging from the character of the locality, not improbably have been the result, and the sole result, of an exceeding saltness of the water. At Auray, in the neighborhood of the natural grounds, Möbius states that far more seed oysters are raised than can ever be grown to marketable size, on account of lack of space and food resources. Judging from what is now being done at Auray, the industry is profitable as purveying seed oysters for the parks in regions (*e. g.*, in Brittany) unfavorable to production. The experience of the Auray culturists does not favor the idea that the lack of oyster food limits *élevage*, but that efforts at collection are of greater advantage commercially.

The law of oyster growth, as stated by Möbius, seems, therefore, from the standpoint of the culturist, open to misconstructions: "Oysters are to be included in the same list with other animals; the sum of their entire mass is dependent upon the amount of food stuff which they obtain and store up,"* becomes truism. This might, however, be thought to imply that the number of oysters in a given river or bay might not become greater because their biocœnose appears to be perfect. Artificialization has demonstrated that the matter of food supply in natural oyster localities is of far less importance than space for culture and immunity from enemies.

Möbius, discussing the possibility of success in the French cultural system, concludes "that in all parts of the Wattenmeer, where oysters could find room and generate, there they already live. On all parts between the natural banks the swimming embryos as they settle, either on account of finding no point of support or through unfavorable living conditions, can not exist. The principal difficulties in obtaining a set on our (German) coast are those of sand or of mud burial."† It has already been shown that difficulties of this character have been successfully surmounted within comparatively recent years in France.

* Möbius, Die Auster u. die Austernwirthschaft, p. 79.

† Möbius, Ueber Austern- u. Miesmuschelzucht, p. 43.

Möbius has, furthermore, supported his view that physical conditions have limited and will limit the size of the Holstein banks, by adducing the matter of percentage of increase. This he has determined by comparison of the number of oysters as fished from the banks to be about 421 "half-grown" to 1,000 "full-grown" oysters. This proportion, it will be admitted, determines the natural increase of the banks, but it can obviously have little to do with proving that artificial production in the neighborhood of the natural banks would be unsuccessful. The French culturist, on the other hand, might well suggest that this proportion of natural increase is a large one, since in French regions most favorable for artificial production the banks, so far from increasing, retain with the greatest difficulty the average number of spawning oysters.

The third reason given by Möbius for lack of German success in French cultural methods is the coldness of the northern winter and the severity of storms, often occurring when the tide is at its lowest phase. It is certain, as Prof. Hoek pointed out to the writer during a visit at the Helder, that the German coast is not far distant from the northern limit of the oyster, and that its natural increase, therefore, is less favorably conditioned. The dangers of the Holstein bank to direct freezing in winter, as Möbius has stated, may well be regarded on every side as formidable, especially in artificial production, where young oysters affixed to the collectors are to be retained during the winter. These dangers would appear, however, to render success with French culture costly rather than impossible, necessitating the transfer of collectors to deeper water or to localities that have proven safe, or, as in Brittany, providing special reservoirs for winter storage.

That natural banks exist even in great number in the Wattenmeer, and that the Danish banks, which are located considerably to the northward, appear to bear the cold and storms of rigorous winters with more or less success, seem to suggest that a provision for safely wintering oysters, even in the youngest stages, might not prove an impossible task. Indeed, if a good set of oysters were obtained in the German sea by the introduction of improved collecting methods, the use of suitable reservoirs, as those of the government station at Husum, which serve every year to harbor the marketable oysters during the coldest weather, might well be expected to provide safe winter quarters for the young.

The reservoir at Husum (Pl. LXXVIII, Fig. 2) is admirably devised and merits at this point a brief discussion. It was placed at Husum on account of transportation facilities, although its situation is in many regards unfavorable. Husum, as already noted, is at the southernmost corner of the Wattenmeer, probably at one of its most muddy shore points, and its low, rich meadows are strongly protected against storm tides by heavy fringing dikes. These, by an indentation, allow a wide canal to carry freshened water seaward, and thus provide a harbor for the fishing vessels of the little port. The slanting sides of this canal are of the softest mud, reminding one of the great canal at La Tremblade. Its waters, which become almost as salt as the outer Wattenmeer at high tide,* are allowed to pass through a sluiceway into the neighboring government reservoir. The fall of tide, averaging about 10 feet, is sufficient to allow the basins to be emptied daily.

* At low tide (July, 1892) 59° 1.013, at high tide 1.0235.

The following figure illustrates the care with which the reservoir is devised to deprive the water of its sediment. The great dike, which rises almost 20 feet above the normal water level in the basins, is pierced at two points; one, opening on the seaward side (A), feeds the reservoir (B), the other (C) is the outlet of the pond (D) destined for the storage (and fattening).

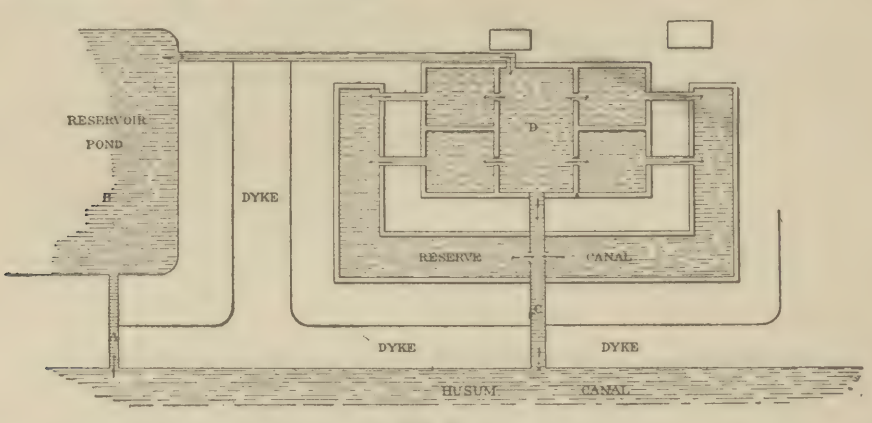

FIG. 3.

The oysters, it will be seen, do not receive their water supply directly from the muddy canal, but from the reservoir pond, where the water from the canal, after standing twenty-four hours, has deposited sediment. The storage pond (D) is subdivided as seen in the figure, and each compartment of the basin may, for convenience in handling, be emptied separately. The outlet gates, it will be noted, do not allow the water to escape directly into the canal without, but pass into a U-shaped canal, which, with boarded sides, is sufficiently deep to contain a reserve supply of water, intended for use in case the reservoir is in process of being cleaned. The main division of the storage pond (D) has a board bottom, raised a foot or two above the soil, through whose interstices the sediment shifts or is swept when the pond is being cleaned. Partitions about a foot in height divide the bottom into alleyways in which the oysters are arranged. These alleyways serve to separate different grades, and are of convenience in the process of washing the oysters. The side ponds, fed from the main pond, are similarly arranged as to the partitioned alleyways, though the bottom is of concrete, or rather of a heavy foundation of concrete veneered with closely fitted firebrick.

The management of these storage ponds is a simple one. The oysters during the dredging season (September 1 to May 8) are obliged to be brought to the station, and are at once transferred from the boat to the basin, to remain only until time of railroad shipment. Improvement in quality of the oyster during this stay in the basin is not taken into consideration commercially. There are apparently no attempts at fattening, flavoring, or "education" for transport, as practiced at La Tremblade. The ponds are daily filled and emptied, so that no time is given for the oyster food to multiply as in *claire* culture. In the neighborhood of Husum the low-lying country is suggestive of Marennes, in its rich sediment-bearing character as well as in the degree of salinity of its waters, and it would appear to the writer that experiments in well-managed *claire* culture (which have not apparently been made) might lead to interesting and perhaps important results.

To summarize, the oyster industry in Germany is entirely dependent upon the surplus of its natural beds. French culture has not been introduced in its behalf, but the writer does not consider it proven that this system is an impracticable one in the German waters, or that artificial oyster-culture is suitable for France and not for a neighboring country. The few experiments tried in Germany with regard to artificial collection have not, as far as the writer could learn, been in accordance with recent improvements. Tiles that have been put out in the neighborhood of the natural banks appear to have been arranged in single tiers, in a way that would have succeeded in the hard river bottom at Jerseke, but would never have been attempted in the sediment-bearing water of Auray. These tiles, placed upon a very muddy locality, were not unnaturally engulfed in part, and in part so covered with sediment that a set could not have been obtained.

The few experiments tried in the government station at Husum have signally failed, the usual fate of experiments upon production in small, closed ponds, where stagnation, *i. e.*, malaëration and fouling of water, caused by death and decay of the spawning oysters, added, in this case, to the dangers of silt deposit, have been the stumbling-blocks. The matter accordingly has rested, and no further expenses have been incurred by government in what were supposed to be fruitless experiments. The dredging contract, moreover, held by a single firm, has been unfavorable to competitive culturists. No foreshore has (until recently) been conceded by government, enabling experiments to be generally attempted or allowing shore basins to be formed as winter quarters for the oysters. Without concessions, case culture could not be attempted, and the introduction of seed oysters from Holland or Brittany has been forbidden on the ground that by this means oyster enemies might be introduced.

All attempts at introducing oysters in the Baltic have been unsuccessful. The brackishness of its water, said to become especially marked during the early spring, is certainly fatal to the European species. The density in the harbor of Kiel (June 29, 1892) averaged 1.0125 at 62° F., and at Cappeln to the northward did not become greater (high tide July 4) than 1.012 (62° F.). A greater degree of salinity at any time, even in this lower region of the Baltic, is hardly to be expected, as the fall of tide rarely exceeds 4 or 5 feet.

The canal, which is now in process of construction, and will allow the water from the North Sea to pass into the harbor of Kiel, may, it is said, have a local effect upon the marine life of the harbor, but can not from its size exert an important effect commercially upon oyster-culture. The change brought about in a similar way at Lijmfjord, in Denmark has, it is true, been an important one, but it should be remembered that the position of this locality is nearer the mouth of the Baltic, where the degree of salinity is naturally higher. Some interesting experiments have been made by the brothers Feddersen, of Schleswig, in introducing American oysters into the Baltic, hoping that this species might be readily acclimatized in fresher water. The account of this trial is recorded in *Prometheus*, No. 116, 1891. Analyses were made of water samples from the Delaware, in the neighborhood of the beds from which the American oysters were to be taken, and these were compared with similar analyses of Baltic water. The average degree of saltness in both localities was not unlike, although at high tide the Delaware water was considerably the more dense (sp. gr. about 1.018). The Feddersens caused forty barrels of oysters to be imported, were obliged to pay

duty upon them as marketable oysters, and obtaining permission of the government planted them upon a submerged platform at a point in the Baltic not far from the entrance of the Schleswig River. The experiments were unsuccessful. The oysters have now been in the Baltic a number of years, and are still living, but their condition is of the poorest; they are thin, watery, shrunken, and have not grown since their introduction.

The Feddersens, in spite of these discouraging results, are resolved to attempt the introduction of the American oyster on the coast of the North Sea. To this end they have finally succeeded in obtaining from the government a provisional concession located near the mouth of the Elbe. This is the only concession that has yet been granted allowing foreign oysters to be planted, and is to be revoked if the imported oysters do not reproduce. The question of importing seed oysters free of duty, and the matter of concessions for their *élevage* is now, the writer has learned, in process of consideration.

The following is an abstract of a lease of oyster-cultural property granted recently by the German administration.

The locality is first described and the term of the holding (thirty-five years) stated. The lessees engage to carry on all negotiations openly and fairly, to be in every way responsible for losses caused by nature or war, to hold the property during the entire stated term, and to appoint and pay expenses of guardians. The administration places the control of the concession under the supervision of the professor of zoölogy at Kiel; he may determine yearly the percentage of the spawning oysters, may regulate the times of dredging and the character of the dredge; he may at all times have permission to make examinations and experiments, and for material thus used no compensation is to be given. The closed season is prescribed; the time of fishing, of which notice should be given, is to be recorded by a foreman, whose books, kept under oath, are at all times accessible. A tabular yearly report is required. Damages by storm are to be reported. Fishing boats must be specially licensed. There can be formed no embankments for oyster parks which might be in the way of passing vessels. Oysters when dredged are to be brought to a stated place for the inspection of the government officials who must be sought for within three hours after the arrival of the cargo. The lessees are then to pay revenue fees for examination in addition to the regular duty on the dredged oysters. Three hundred tons of oysters (ton=700 to 800 oysters) must (in this lease) be sent annually to market, and upon each ton 50 marks (about $12) must be paid as a governmental tax. Above this total production, if dredging is allowed, the original tax per ton is increased by the amount of 10 marks during the first seventeen years and 20 during the concluding eighteen years of lease. In payment four weeks' grace is allowed; thereafter a fine of 10 marks is imposed from the first week and 50 for the succeeding one. Taxes may be imposed as upon real property. Security must be deposited by lessees (in the present lease to the extent of 15,000 marks) in government securities, whose coupons can not be separated during time of deposit. In case of loss or theft of securities no compensation may be obtained. Legal transfer of deposited securities can only be made by governmental consent. Heirs who inherit a concession are required to renew the securities. In case the lessees fail in their responsibilities, the lease with the government becomes broken and is revoked. Improvements to property may, at option of government, be taken at its own valuation; incumbrances are at expiration of term to be removed at the expense of the lessees.

OYSTER CULTURE IN HOLLAND.

The Dutch have come to be looked upon in Europe generally as the most successful administrators of the oyster industry. A potent, not unnaturally a selfish, reason for this, no doubt, has been the direct importance of their fisheries. In the case of oyster-culture an industry has been fostered which not only gives employment to its poorer coast population, but pays into the national treasury, in rental of state lands hitherto absolutely profitless, an annual income of nearly a half million of dollars, a sum not inconsiderable to so small and thrifty a country as Holland. In view of the keen competition for leaseholds of cultural lands, and in consideration of the necessarily limited area devoted to culture, in all not as great by half as that of Long Island Sound, these facts seem to demonstrate that the management, both on the side of the government and of the culturists, has been a prudent and energetic one. The processes, both administrative and cultural, have in specialization become somewhat different from those of France, consequent in the main upon changes in local conditions. They are, therefore, interesting to study, especially as almost every modification has been evolved democratically, of the people and for the people.

The history of the government's policy in the administration of the industry may be briefly outlined as follows: The natural banks had been overdredged, practically destroyed, the usual fate of the European oyster banks, those of Germany alone excepted. This state of affairs, it must be noted, came to pass, although dredging had been rigidly confined to no more than five months of the year (October to February). The banks of the Zuyder Zee were destroyed and the overdredging in the richest natural grounds, those in the estuary of the Schelde, had rendered them well-nigh profitless. Interest on the side of government appears first to have been aroused by a petition coming from energetic culturists, who desired that lands should be conceded to them and that a thorough study be made of the life history of the oyster. A number of these gentlemen had independently visited the regions of French production and understood clearly the value of artificial culture in their own localities. In 1870 the course of the administration was determined, and has since been followed with but slight modifications. Its underlying principle, an heretical doctrine it doubtless seemed at that day, especially as even the French had not gone so far in the matter of innovations, was to do away with public dredging entirely, to survey off the natural oyster-grounds and their surrounding waters, and to lease these tracts at prices to be determined by open competition. This course was at first strongly and bitterly opposed by the fishermen, who (as in New York, Connecticut, or North Carolina), not knowing the benefits which might arise, feared the direct loss of what they regarded as a patrimony, and who, as a major reason, were not anxious to pay for what had formerly been almost free. The survey was finally completed, the east arm of the Schelde, the region most favored, being marked off in shore and deep areas, each of about 12 acres, by lines more or less perpendicular to the direction of the stream. These were then put up at auction and leased.

No restriction was imposed. The rental of the property was to be paid yearly, and in 1877 the beginning was made of a fifteen years' lease, with the option of giving up the lease at stated times. The second re-rental of the property, however, was arranged to take place several years before the expiration of the lease, and was to allow a term of thirty years, with option of giving it up every five years.* The present experience in the renting of the returned parcels, as explained to the writer by Mr. C. J. Bottemanne, inspector-general of the Holland fisheries, indicates that a shorter term of lease will in the main prove more satisfactory to the government as well as to the tenant, the government getting a fairer proportional rental, the tenants being more apt to have a better opportunity of obtaining favorable concessions. A yearly lease of all state cultural property is now to be inaugurated, with a right to have this twice renewed.†

The actual oyster-grounds of Holland may be grouped as those of the Zuyder Zee and those of the Schelde estuary. The former, in spite of all efforts at their regeneration, have remained profitless, and the lack of success in these measures is attributed partly to unfavorable conditions of a northern locality and partly to variation in water densities.‡

The Zeeland grounds, those of the Schelde estuary, became from the first the seat of the oyster industry. In the east arm of the Schelde the most favorable conditions exist for growth and production; and here, in fact, is the only point in Holland where the artificial collecting of seed oysters has been profitably carried on. This region has proved a favorable one in the firm unshifting character of foreshore and even of deeper areas, and in the degree of salinity of its waters. The densities, it may be noted, varied between Goes and Bergen-op-Zoom at different tides (July 16 to 20, 1892) between 1.023 and 1.015 (62° to 69° F.), conditions that appear to correspond very closely to those of regions of production in France (Auray or Arcachon), although in the latter instances the water temperature at a corresponding season the year before was warmer by 5° to 10° F.

It is in the East Schelde that the biological problems connected with the oyster have been studied—from the time, in fact (1870), when a critical investigation of these matters became necessary. To carry on observations as near as possible to the seat of the oysters spawning, the Dutch Zoölogical Society made use of a portable laboratory, and under the auspices of this society were prepared the classic memoirs of Hoek, Hubrecht, and Horst.§ The embryology of the European oyster was here given its most careful study. Experiments were made upon the collecting of seed oysters in small closed ponds in which the water was aërated artificially, and the questions relating to the spawning of oysters in captivity were investigated, since in all experiments the impracticability of fertilizing the eggs of the European oyster proved a very serious difficulty.

Certain problems connected with the East Schelde seemed also especially to require solution, such as those of the movement, duration, and distribution of oyster

* Hubrecht, Int. Fisheries Exhibit (London), pamphlet, Oyster-Culture in Holland, 1883.

† See pp. 387 and 388.

‡ Dr. Hoek, in conversation with the writer, at the Helder, July 18, 1892, commenting upon the failure of recent experiments in the Zuyder Zee.

§ Rapport sur les recherches concernant l'huitre et l'ostréiculture, Leide, Brill, 1883–84.

fry. There remained also to determine the location of the oyster supplies whose spawning products insured the general productivity of the region. That these supplies existed was undoubted, since, on account of irregularity in spawning, the supply of cultivated oysters could not be regarded as adequate to furnish the myriads of spat which made production in the East Schelde profitable.

It was at first thought that large natural beds existed seaward, but systematic dredgings carried on by a government steamer proved conclusively what the fishermen had always claimed, that natural beds did not occur in that direction. Unexpectedly, however, it was afterwards found that extensive banks of oysters were safely sheltered at the foot of the dikes, and these had been the undoubted source of fertility of the East Schelde. There had long been a law which, with a view to protect the stone defenses at the foot of the dikes, had forbidden the use of dredging implements of any description within 500 meters from the coast. There had thus inadvertently been allowed to remain, as a fringe circling the Schelde, a strip of natural undisturbed oyster-bearing land, to serve most conveniently in place of extensive and localized natural banks. The conditions of these fringing banks have since been clearly determined, and, from examinations made by a diver, charts have been prepared showing the size and position of these unsuspected sources of oysters. The Dutch system of protecting the natural banks will accordingly be seen to differ very little in its end from that of France, where, in general, governmental grounds are only exceptionally to be dredged upon, and where the rigid preservation of natural undisturbed oyster banks is regarded as the most fruitful aid to the oyster industry.

The management of a cultural establishment in the East Schelde can, after these preliminaries, be better understood. As a practical consideration it may, however, be noted that each lessee of oyster property has found it to his advantage to secure plots at different points scattered throughout the Schelde Basin. By this means he has found that all branches of his industry may be carried on at a minimum cost. He may, for example, collect his seed oysters on tiles at one favorable point of the basin, where he can not, either on account of interfering with navigation or of danger from cold and storms, allow them to remain during the winter. He must then transfer them to another plot which, from depth of water and favorable conditions of bottom, insures their safety during cold weather. He must also have a series of inclosures (parks) in shallow water, where conditions for growth and fattening may be more advantageously given. It may be convenient, in discussing the processes of Dutch oyster-culture, to consider them as: (1) those of production, *i. e.*, collecting seed oysters; (2) those of deep-water culture; (3) those of culture in inclosures. It will be remembered that in French oyster-culture, production and *élevage* in inclosures were alone included, and that it was exceptional from the natural character of localities that an *éleveur* might at the same time collect his seed oyster. In the East Schelde all branches of the industry come naturally in the province of the culturist, because, practiced in the same locality, each culturist would have as good an opportunity to excel in each branch as any of his immediate neighbors.

PRODUCTION.

To obtain seed oysters is the most important as well as the most troublesome task of the Dutch culturist. He must first lease a favorable plot in the outer and deeper portion of the East Schelde, a rather difficult and hazardous task at the best. A locality which this year may have been very favorable, may the next year diminish in value, and a third year be worthless. A plot let in 1870 for 40 cents brought at auction in 1885 over $1,000, while on the other hand a plot which in 1877 sold for $200 brought two years later less than one-thirtieth of that price. These extreme cases indicate clearly the direct influence of slight changes of current on the disposition of the oyster fry. It is admitted that the best localities for collecting are those where a strong incoming current is broken into eddies by opposing currents deflected by banks or headlands. At such a point a saucer-like depression of the bottom is regarded as the veritable gold mine of its proprietor; here the tiles appear to be kept clean by the circling current and are usually found crusted with the depositing spat. After a suitable ground has been obtained the second task of the culturist is to prepare his collectors. For this purpose, following the lead of the French culturist, he has found no better device than the roofing tile.

The Dutch tile is stout, square, and heavy, mounted with pegs, so that when put on edge side by side (see Pl. LXXX, Fig. 1) the faces do not come in contact. These are usually purchased from Belgium, and cost when delivered in the Schelde about $4.25 a thousand.* The length of time for which a tile is serviceable, *i. e.*, before becoming brittle and broken, is about eight years. The process of coating the tile with chalk (*chaulage*), to render the young oyster readily detachable, is usually performed by contract on the property of the culturist, the liming mixture differing little in ingredients from the formula in use at Arcachon, *i. e.*, three parts sand, one part quicklime, mixed with sea water until creamlike in consistency. After the tiles have been dipped in this lime bath and arranged in banks to become dry, the entire margins of the Schelde may be seen outlined, as if with massive snow banks, which shortly melt away as cargo after cargo is carried off to the collecting-grounds (Pl. LXXIX, Fig. 1). About 16,000,000 tiles are sent out from the neighborhood of Bergen-op-Zoom for distribution on the lower parts of the river.

The process of transferring the tiles to the grounds is as follows: A small railroad conveys the loaded hand cars (Pl. LXXIX, Fig. 2) to the fishing vessels engaged by contract for the needs of the season ($10 per week with two men). The vessels when laden proceed seaward to their grounds at high tide, the cargo is hastily cast overboard, and the boat returns; meanwhile, as the tide descends, women proceed to the grounds from the shore and hastily arrange the tiles side by side in fringing rows (Pl. LXXX, Fig. 1).† These processes continue for about two weeks during the middle

*A group of about a dozen superimposed tiles hung together by means of a galvanized wire (bouquet) is supplied by contract, and is employed by several culturists for collection in deeper water. The bouquets are secured by a connecting cable of steel wire.

† Mr. Ochtmann has obtained favorable sets upon tiles banked in rows in the marginal tidal inclosures. This appears, however, to be exceptional. The rising flood which is allowed to fill the inclosure and be retained is held to be richest in fry.

of July. The tiles are arranged, as represented in the figure, in a single tier, quite different from the method pursued in the muddy waters of Auray or even Arcachon. The bottom is firm and unshifting, there is little danger of silt deposit, and accordingly it would be in a measure needless to raise the tiles in cases or camions. It is claimed on the other hand that, even if more oysters be obtained by arranging the tiles in layers one above the other, the upper oysters are apt to be lost on account of lack of moisture, the tiles over the ground appearing to absorb and retain moisture more favorably.

During the summer tiles are constantly shifted, sometimes changed in position, at first perhaps as often as once a week, in order that the silt-covered portions may be swept clean by the rising tide, and that the enemies of the oyster (crabs, and especially starfish) may be removed. A constant corps of attendants, mainly women, is therefore to be employed, whose wages add not a little to the cost of production. Shifting of tiles becomes less necessary as fall approaches. As the next process the tiles are to be taken into winter quarters to avoid the danger of "frosting" the young oysters while in the shallows, a danger which appears to be more feared than that of actual water freezing. A term of the contract also prescribes that the tiles be entirely removed from the river basin by December 2, a regulation aiming to prevent damage to sailing craft. The transferral of tiles is effected as before. They now return to the dikes spotted here and there with incrusting oysters. As many as forty to a tile is regarded as an exceptionally favorable set, a number so small that it is a matter of wonder to the Arcachon culturists that production in Zeeland can be profitable.

In the winter the tiles are arranged in inclosures (parks) at the foot of the dikes (Pl. LXXXI, Fig. 1), where a water depth of about a meter may be retained to guard against the danger of freezing. These inclosures may be in high or low ground, may run lengthwise (Pl. LXXXI, Fig. 2) or crosswise of the dike, and in many instances have been constructed within the dikes in polder land (Pls. LXXXII and LXXXIII).* The plan in general, like that of Marennes or the French culturists generally, seems to favor collections of small basins rather than large separate ponds, on account of convenience in cleaning and emptying. It is seldom that the young oysters are detached from the tiles during the fall, a practice usual throughout southern France. The young oysters in Zeeland are said to be much smaller than those of equal age in France, and perhaps on this account are able to sustain cold better when attached. The process of separation, or *détroquage*, begins with the end of winter. The scaling of the young oysters from the tile is, however, far more carefully performed in Zeeland than in France. The set is so scanty that every oyster must be saved and therefore the shoving thrusts of the flat knife blade of the Arcachon *parquer* must be replaced by a circling cut outlining the oyster on the limy crust of the tile. A second turn of the knife now separates the oyster neatly. It seems to be an object with the culturist to have his *détroquage* performed as early as possible in the spring, so that the oyster may not acquire an undesirable flatness and concavity of shell that long attachment to tile is sure to give.

* H. Ochtmann, of Goes, has in the central pond (figured in Pl. LXXX) storage capacity for 1,000,000 oysters. Sp. gr. of these ponds slightly less than that of the Schelde (1021.50, 62° F.).

ÉLEVAGE.

The young oysters, as they are separated, are at once removed to ponds outside or inside of the dikes. Sometimes, if the bottom is suitably hard, they are scattered broadcast over foreshore areas. Sometimes they are for a month or more arranged in two-trayed cases of wire gauze (Pl. LXXXII, Fig. 1)* in cement and brick tidal inclosures until the thin shells have become hard enough to permit transfer to the oyster-grounds.† Although the oysters may be and are grown within the inclosures, each culturist has usually plats of ground located at favorable points in the Schelde basin, where a hard bottom, continual current, and suitable water depth permit planting to be carried on exactly as in the Long Island waters of New York State. In these localities the proprietor dredges his oysters, often shells his land during the spawning season in a way quite American, and sometimes secures in this way a quantity of spat.‡

The value of shelling as a collecting method is, however, regarded as secondary, the improvement of the ground being of the first importance. The shells are found to become rapidly silt-covered and unsuited as collectors. Some proprietors (as Mr. Ochtmann, at Goes) have such extensive plantations of this character that dredging by steam has been found necessary. An example of such a dredging vessel is figured. (Pl. LXXXIV, Fig. 1.) Oysters on this deep-water ground (rarely more than 12 feet) remain exactly as with us, growing rapidly, struggling with their enemies, and doubtless contributing their spawn to the general fertility of the Schelde waters.

The above outline of the cultural processes in Zeeland may be concluded with the following notes:

(1) In regard to expensive character of production: The industry is alone rendered possible by the price attained by Dutch oysters throughout central Europe, especially central Germany, where every town has an agency of a well-known culturist who supplies oysters from the Schelde or Ostend (*i. e.*, English ? oysters). One of the most influential culturists, Baron Groeninx van Zoelan, to whose kindness the writer is greatly indebted, has stated that during the processes of collecting each tile is handled no less than twenty-one times. The total annual expense per tile (including breakage, *chaulage*, transportation, shifting, reloading, *détroquage*, arrangement, etc.) amounts, however, to not more than 4½ cents. Second-year oysters are said to have little market in Holland. The total cost to the culturist of a three to four year old oyster can not, the writer estimates, be much less than 3 cents, *i. e.*, including packing and transportation to railroad station.

So great an amount of capital must be invested in a cultural establishment that the industry has naturally fallen into the hands of companies or of wealthy and energetic proprietors, among whom nothing but keen competition, especially as to the

* The use of these cases is not popular in Zeeland. Their cost is great, and the more rapid growth that they foster is, it is claimed, not sufficient to make their use profitable in a locality so little disturbed by sediment deposits or invasions of enemies as the Schelde.

† The young oysters are often passed through sieves and separated roughly into their grades, which are then usually to be planted in different localities.

‡ H. Ochtmann, of Goes, one of the largest culturists of the East Schelde, is greatly interested in the question of the productivity of a well-shelled bottom. During the present season he has prepared more than 20 hectares in this way, but at the time of the writer's visit the result, though still doubtful, was decidedly favorable to the tile system.

acquisition of leaseholds, has prevented monopoly. It appears to be evident to the authorities, however, that cultivation carried on generally on a small scale would not be as productive either to proprietor, employé, or state as the present system. Competition in price with foreign oysters is, it is claimed, the safety valve of the Dutch system of oyster-culture. It is instructive, however, to find that foreign seed oysters can not be imported into the East Schelde (although they may be in immediately neighboring waters). The reason is a commercial one, albeit the culturists maintain that they are struggling to prevent the importation of oyster enemies. The outcome of the discussion during the past year between Prof. Hoek and Mr. van Nisse* will, it is expected, be the importation of French seed oysters, whose cheapness can not fail to have an effect in decreasing local production, extending *élevage*, and reducing the market price of the Zeeland oyster.

(2) As to the leasing of state oyster lands and oyster legislation: Holland has no laws governing the oyster industry; that is, in the sense of general laws. Thus, for example, there is no season when oysters must not be dredged or marketed. This no doubt is the consequence of leasing out the oyster land and of the absence of public grounds from which the oysters may be dredged. The oyster laws thus disappearing, their purpose is, however, retained, but in a more personal manner. The state becomes a landlord, whose lease is law to the tenant. The board of fisheries determine what each lease shall be, its duration and conditions, and sell it by auction to the highest bidder, claiming thereby to adjust with greater nicety the requirements of state regulation to natural local conditions. A law suited for one cultural locality, it is claimed, is severe for another; even a part of a locality is not to be governed by the restrictions applicable to cultural needs in shallower or deeper water. The terms of leasehold are studied, as may well be done in so small a district, by the inspector of fisheries, whose report suggests needful changes or alterations. Land hired for oyster-culture, it is argued, is like that hired for farming. If a person secures a good lease, and is deriving a good profit from it, he must be willing to bid in its leasehold, but at the same time his neighbors have an equal right to compete for it. Thus it is best for both tenants and landlord, the state as the landlord deriving, no doubt, an immediate benefit from this course of policy.

All lands suitable for oyster-culture may be leased, their value naturally depending on their situation, suitability for collecting and for *élevage*, the length of time under water, and the character of bottom. In favored localities the tracts grow smaller as competition for their leasehold increases. Polders (waste land behind dikes) may be converted into oyster parks and become profitable to the state as well as to individuals when rented under the same conditions as the outside property. The lease between landlord and tenant represents the code of the oyster industry.

Each year the sale of parcels of land is advertised. A catalogue prepared by the inspector of fisheries, Mr. C. J. Bottemanne, announces the plots to be leased, the terms of the contracts, and the time and place of the sale. The conditions under which the present leasehold is given may thus be briefly stated, translated from the Voorwaärden van Verpachting van Vischplaatsen Schelpdieren-Visscherijen en Weervisscherijen, Ooster-Schelde (Tholen, 1891). The auction takes place in a notary's

* Verlag van den Staat der Ned. Zeevisscherijen, 1891, pp. 83, 84.

office in Bergen-op-Zoom between 11 and 4 o'clock, seventy parcels to be sold each day. The sale of leasehold is to the highest bidder. Should no bid be received for a stated plot it is joined to the next plot to be put up. Those only are eligible as leaseholders who are natives of the Netherlands, who are not indebted to the state, and who can furnish two responsible bondsmen. In case of doubt in regard to bids the plot is to be at once put up and resold. A deposit of 5 per cent of the yearly rental must be made at the office of the secretary of the board of fisheries within eight days from date of sale, and a formal written lease of the parcels may there be obtained at a stated fee for copying. Yearly rental for oyster plots must be paid by the 1st of March. In inaccuracies in surveying the government—*i. e.*, board of fisheries—is not to be held responsible. The lessee, however, must know his boundaries. He has no right to make use of land that exists or may exist between boundary lines. No redress is to be obtained for damages to leased property* occasioned by navigation or on account of natural causes, direct or indirect, consequent upon changes made in governmental drainage of land. Property can not be divided or subleased without written consent of the board of fisheries. Lessees are responsible for damages to their neighbors as well as to the state, but the state does not become responsible for the damages of a lessee. The numbering of the boundary stakes is intrusted to tenants, with a fine of 25 florins ($11) in case of neglect; when deranged on account of storms they must be promptly replaced. In the meanwhile, however, trespass is punishable by a fine of 50 florins. Culturists whose territories do not touch the bank have at low tide the right of way between their neighbors' grounds. The shortest way to such ground is alone permitted under penalty of trespass, and in this regard, as in all others, the lessee becomes responsible for the doings of his employés. The culture of mussels is forbidden on property rented for the culture of oysters, punishable by a fine of 100 florins. The mussels, if not at once removed by the lessee, may be removed by state authority at the expense of the offender. Foreign oysters are not to be introduced (in the East Schelde only). Those, however, dredged north of a line drawn between Dover and Dunkirk may be planted, if with stated consent of the board of fisheries. Dredging at night (one hour after sunset to one hour before sunrise) is punishable with a fine of 100 florins. Dredging vessels shall be numbered at the bow and on the sail in characters of a stated size. Water courses must not be interfered with. Any obstructions of this character must be removed within twenty-four hours after notification by the board of fisheries, or shall be removed by the state at the cost of the lessee. The lessee is responsible for the amount of his lease; if his holding when sold does not furnish this amount, he is to make good the difference. All rights in oyster-cultural property are to be in every way subordinate to those of the administration of dikes and waterways. Different parcels of land are to be given leases of different duration. An annual lease at option of tenant may, in stated plots, be twice renewed.

* A regulation not here stated provides that tiles used as collectors shall not remain in the navigable waters later than December 1.

OYSTER-CULTURE IN BELGIUM.

The oysters of Ostend have long been especially esteemed for their flavor. Parks, or, more accurately, *claires*, reservoirs for oyster fattening, have been in use over a century. The location of Ostend has not favored the formation of natural banks, and the few that existed were early dredged out and destroyed. Efforts that have occasionally been made to replenish them have been fruitless in every case. Without banks no governmental restrictions have been laid upon dredging, and production can not be attempted. The Belgian coast seems in every way unsuited for planting purposes, and the river basins and open canals are so liable to mud accumulations that their use would be impracticable, no matter how favorable the character of their tidal waters might be for purposes of culture. The region, in fact, is in many regards comparable to that of Marennes. There is a low-lying country, a sluggish river, the Yvres, and a series of branching canals which freshen the tidal water and appear to be surprisingly rich in oyster-food organisms. It is not unnatural that *claire* culture should have been here introduced, and that these ponds should have been dug on either side of the main canals where the character of the tidal water had been found most favorable.

Belgian oyster-culture is accordingly to be reviewed in its single aspect, that of *conditioning*. Ostend stands as one of the most important oyster depots of Europe, derives its oysters from neighboring countries, and after a few weeks or months is enabled to distribute them as Ostend oysters to England, Germany, and France. The industry appears to have grown up naturally and quietly, almost, in fact, before the government was aware of its importance, and perhaps mainly on this account the culturists are allowed to continue their operations almost entirely without state restrictions. Concessions for cultural purposes are rarely, if ever, obtained, the lands occupied by the dozen or more establishments dotted along on both sides of the Ostend canals being, with scarcely an exception, the property of the culturists or of their individual landlords. These establishments are regarded simply as private storehouses, whose supply of water from the canals is allowed to be taken by an apparently tacit permission of the authorities.

The cultural processes of Ostend vary but little in the different establishments and are easily understood. As a convenient type, that of Messrs. Stichert & Stracke may be taken. This is courteously open to the inspection of visitors to Ostend and is admirably managed. It borders the canal at the side of the highway to Bruges, and is but a few minutes' walk from the city. A *claire* basin about a hectare in extent has been dug out (Pl. LXXXV, Fig. 1), which takes directly from and empties its waters into a main canal (Pl. LXXXIV, Fig. 2). The basin may, at high tide, admit the fresh supply to a depth of about 7 feet; its bottom is level, of compact clayey mud, with masonry, however, near the margins; and its sides, as will be seen from the figure (Pl. LXXXV, Fig. 2), are carefully turfed. This is the main or reservoir basin; it receives the turbid water of the canal, allows the sediment to be deposited, and serves, doubtless, in generating oyster food. This reservoir may readily be emptied, dried, and cleaned whenever the deposit of mud becomes inconvenient. A corner of this main pond, as represented in the figure, has been inclosed by masonry walls, and it is

only this portion that is destined for the oysters. It is entirely of concrete, its waters drawn from the reservoir pond being now regarded as free of sediment and rich in food organisms. The density of the water (July 19) remained constant in the canal and ponds at 1.023 (61° F.), a uniformity of saltness which is no doubt in part dependent upon the locks which occur seaward, and the tide water is perhaps proportional in incoming volume to the brackish water entering landward.

It is certain that the conditions of water in the reservoir are extremely favorable, and that the food therein provided is sufficient to feed a half million of oysters thickly stacked, a remarkable number for an area so restricted. Processes like those of Marennes, intended to richen the supply of oyster food in the reservoir, do not appear to be employed. The water, naturally rich in suspended organisms and their food stuff, is perhaps bettered in its conditions for oyster feeding by remaining a day or two standing, and is made use of before becoming deaërated. The *claires* of Marennes, on the other hand, renew the water but seldom (fortnightly), secure aëration by maintaining only a slight depth of water (10 inches), dry out the bottom regularly, and are even spaded up to richen the food stuff of the organisms which are to fatten and color the oysters.

The Ostend principle of frequently changing the water in the reservoir renders it unnecessary to spade up or specially arrange the *claire* bottom, and at the same time does not tend to green the fattening oysters. The low *claires* at Marennes, where the water is often renewed, produce white oysters, while the high *claires*, it will be remembered, develop the green moss, *Amphipleura* (*Navicula*) *fusiformis ostrearia* Grun., in quantity. Frequent changing of the water tends, moreover, to lower the mortality in *claire* culture.

At Ostend oysters are received continually from England, France, or Holland, and are at once placed in the concreted compartments. They are banked several tiers thick, and are often arranged in a series of parallel alleyways formed by low board partitions. Their time of arrival is registered, and a month is usually allowed them to acquire the taste and appearance of Ostend oysters. The only process to which they are subjected is that of cleaning and rearrangement. This is performed by the attendant before renewing the water supply, by shoveling them roughly to and fro in the different alleyways as the water is passing out. The roughness in this process may, from attrition, not improbably account for the smoothness of shell which forms one of the characters of the Ostend oyster. This local character, observes Leroux,* is also attained by a regular course of shaking the oysters in bags; it is suspiciously claimed by the rival culturists of Zeeland that a stamping machine is in use to break the fringing edges and favor the production of a smoothly rounded shell margin. Higher water temperature marks a slight modification in the management of the basins. Oysters that are to remain during the summer are disposed not so thickly in the cemented compartments, are more frequently shifted about, and are given fresh water from the reservoir as often as twice a day.

The importance of Ostend is understood when we consider the constant stream of oysters that passes through the dozen or more establishments during three-quarters of the year; and a calculation might, in a general way, be based upon the storage

*Traité pratique d' Ostréiculture, Nantes, 1881, p. 30.

capacity of a single park, such as the one described, which is, at the greatest, about a half million oysters per month.

The grades of oysters furnished by an Ostend firm are in order of value about as follows: (1) Native Whitstable; (2) native Colchester; (3) Burnam native "nut" oysters; (4) Victoria natives, a French oyster transplanted in the Thames estuary (these grades are said to stand two weeks' transportation and storage); (5) French oysters (from Brittany mainly), said to bear a week's storage; (6) the Dutch oyster (Zeeland), placed as the lowest grade, perhaps for commercial reasons.

In the neighborhood of Ostend the Belgium coast furnishes two more localities for oyster conditioning, one at an eastern coast suburb, Blankenberghe, the other to the westward at Nieuport. The establishment of Dr. Anselme ver Nieuwe at Blankenberghe (Pl. LXXXVI, Fig. 1), differs somewhat from those of Ostend, and should be briefly noticed. It is near the Blankenberghe sea dike, and draws its water from a canal near its outlet into the sea. This canal as it backs up its waters before they are allowed to escape, forms a kind of *claire* reservoir, slightly brackish,* where the silt is deposited before the water is drawn by the culturist into his fattening "pits" or small cemented basins. Gates lifted by a cog windlass enable the water to be taken in daily or to escape. The cemented pits are separated by masonry walls into four side-by-side compartments, each about 30 by 20 feet, and may be separately emptied or filled. In each compartment are low longitudinal partitions of boards, between which the oysters are thickly stowed, and are daily shoveled to and fro as at Ostend. A depth of about 8 feet of water is normally maintained. The oysters become in condition in about three to four weeks.

At Nieuport the establishment of Meinesz & Co. (Pl. LXXXVI, Fig. 2) presents a number of modifications of the usual Belgian processes. Cultivation proper, *i. e.*, the raising of marketable oysters from imported seed (from Brittany) is here carried on. The principle is that of Ostend, but is favored at Nieuport by making use of an old fortification whose U-shaped moat forms a large reservoir pond. The two cultural ponds lie end to end between the arms of the U. It will thus be seen that the water, which may be admitted from the canal emptying into the harbor, may first be passed into the end of the reservoir pond, and in escaping may be made to form the circuit flowing out through the cultural ponds at its original point of entrance. The reservoir ponds, although shallow, appear to contain several times the water volume of the cultural pond. The water density of the latter slightly freshened from the canal and harbor, perhaps also by surface drainage, was at the time of the writer's visit 1.021 to 1.022, at 59° F. As at Ostend, the reservoir is daily filled and at low tide on the following day, when the water has become nearly siltless and richer perhaps in food organisms, the contents of the reservoir will be allowed to flow into the cultural ponds.

All ponds appear to be channeled along the median diameter (where sediment accumulations may be readily removed), and a normal water depth here of about 6 feet decreases gradually to the margins. The reservoir ponds are earth-bottomed; the cultural ponds are mainly of concrete. The richness of the organism element of the reservoir water is, as at Ostend, attested by the remarkable numbers of oysters which are here cultivated. Each cultural pond measures 20 by 200 yards, and, as the illus-

*Water in the pits was 1.022 at 60° F., July 29, 1892.

tration shows, is filled with wire-gauze cases (3 feet 6 inches by 3 feet 6 inches by 2 feet 6 inches), in transverse rows of sixteen. Each case contains no less than three or four trays of 300 to 400 oysters each. The cultural processes appear to be simple, consisting merely in rinsing sediment from the trays and allowing the muddy water then to be flooded out. The loss of young oysters during the first year is said to be considerable, amounting to almost 25 per cent, a mortality for which no doubt the settling of a heavy sediment is partly responsible.

Belgium, in summary, represents the oyster industry in but little more than a single stage—that of *conditioning* or fattening. Production is not attempted, there are no natural oyster banks, and the sediment-bearing character of the water would, it seems probable, be greatly adverse to this branch of culture. The natural richness of the feeding conditions of the Ostend waters is due, it appears to the writer, to a favorable density of the water (about 1.022 to 1.023), together with the remarkable richness of the incurrent canal water in the food stuff upon which the oyster food organisms multiply rapidly. This, attested by the remarkable number of oysters that are quickly conditioned in a given water volume, has (1) allowed Ostend to become a depot and center of supply of almost every grade of foreign oysters, and (2) permitted the conditioning to be carried on within a small area. Private property, therefore, has come into use instead of state concessions, and brings with it rights of permanence and freedom from conditions.

Independence in the management of each establishment seems to have been under the local conditions naturally developed and very successful. The governmental action in whatever has been done, has, accordingly, aimed merely to favor, as far as possible, the making of private property valuable for culture. The new canal, projected by the authorities,* will thus directly benefit the adjoining properties and will, thereafter, from the economic side, become of state importance.

* Bull. Mens. de l' as. com., mar., ind., et agr. d'Ostende, Apr., 1892, p. 206.

THE OYSTER INDUSTRY IN ENGLAND.

The following discussion is intended to summarize the chief features of English oyster-culture, and to show its present position from the standpoints of dredger, culturist, and government. The subject may conveniently be examined under three general headings: (1) the natural supply of oysters, (2) the granting of foreshore for purposes of culture, and (3) the cultural processes.

THE NATURAL SUPPLY OF OYSTERS.

The natural supply of oysters in Great Britain has been among the richest of Europe, and the quality as well as the quantity of the English oysters appear to have been noteworthy from the earliest times, as their merits are often recorded enthusiastically by Roman authors.*

There have been points in all of the many estuaries indenting the British islands where favorable conditions have produced natural oyster beds, which have become exhausted only within very recent years. In some localities the extreme saltness of water has not been favorable to rapid production, and these older and more slowly growing banks have been the first to succumb to overdredging.

Estuaries, on the other hand, whose entire water volume has been tempered with a steady proportion of fresh water appear to represent the oyster's natural breeding-grounds, and have retained their fertile character to a remarkable degree, even after the beds of spawning oysters have been well-nigh destroyed. Of this no better instance can be furnished than of the broad wedge-shaped indentation that forms the estuary of the Thames. This, although the most thoroughly-fished oyster-ground of England, and at the same time the nearest to the London market, has nevertheless held its reputation, even to the present day, as a natural "spatting" ground. It is noteworthy that on all sides there are in this region incurrent fresh-water streams which tend to keep the density of the entire volume of water slightly reduced. At the head of the estuary is the entrance of the Thames, whose channel passes down the axis of the wedge and separates naturally the shallow waters of Essex from those of Kent. On the south side of the channel are the Kentish flats, probably the richest and most famous of known grounds for oyster fattening. These begin at Havesham, under the lee of the isle of Sheppey, fringe the southern shore with an oyster-bearing zone of 2 or 3 miles in width, and extend seaward almost to Margate. There are here included about 30 square miles of cultural ground, upon which the depth of water at low tide varies from 1 to 2 fathoms. The bottom, as a rule, is hard, compact, clayey, and little apt to shift, and by continual processes of dredging and reshelling has been made smooth and clean. Midway between Sheppey and the sands of Margate is Whitstable, which overlooks the best portion of the Kentish flats. The water density here was (August 16, 1892) 1.025 at 64° F., and appeared to be remarkably uniform at both tides from the shore to the channel.

* Cf. Dr. Philpots "Oysters, and all about them," Richardson, London, 1890, p. 4 *et seq.* Hoek, Rapport sur les recherches concernant l'huître et l'ostréiculture, Brill, Leyde, 1883–84, introd.

As a fattening ground for oysters this locality is regarded as not a little dependent upon the outcrops of the Sheppey clays, as these may naturally be regarded as furnishing the pabulum for the rapid development of the minute plant organisms which become the food of the oyster.

The northern or Essex side of the Thames estuary receives a series of small incurrent rivers and is, therefore, in its shallower portions slightly fresher than the waters of Kent. Production of seed oysters appears to be most successful in and near the mouths of these rivers, where, other things being equal, the density is lower (*i. e.*, about 1.022 to 1.023).* This oyster region is famous at three ports—the river Crouch near Burnham, the Blackwater, and the Colne near Brightlingsea (Colchester); notes upon the cultural measures at these localities will subsequently be given.

The natural oyster-grounds have not escaped the fate of those of neighboring countries during the period of their public dredging. The region of the Thames, notwithstanding its fertility, could not endure the increasing strain upon its resources, caused by the demand of the neighboring London market. The effects appear to have been felt first at Whitstable, as the district whose oysters were most sought for, and not unnaturally caused this center to become the depot of the producing region of the Thames, draining its supplies for growing and fattening from the Colne (1866),† the Blackwater, and the Crouch. Here too the effect of overfishing soon became evident; the natural oyster-grounds were exhaustively dredged and the quantity of seed oysters became less and less. All British estuaries were now, one by one, laid under contribution by the increased demand, until at length their natural resources became overtaxed. The demand had then to turn to the continent for its principal supply of seed oysters, which had there come to be produced cheaply by artificial means.

As the natural beds have at all points been depleted, so have the chances of a heavy natural spat‡ appeared to grow less and less; popularly this dearth of spat is generally attributed not more to overdredging than to the lack of favorable or "spatting" seasons (*i. e.*, warm summers with absence of storms or winds), and the exceptional years of 1858, 1859, 1866, and 1881 are looked upon as direct proofs of climatic influence. The reappearance of "spatting" years is generally looked upon as positive, although irregular in occurrence to a noteworthy degree, in general, however, to take place "three times during a lifetime." This firm belief in the natural and unfailing productiveness of the oyster-grounds has only been equaled by the dredger's steadfast view, which gives him birthright from the days of Magna Charta, to fish as often as possible upon the public oyster banks, and to resent as a personal injury all authority to reserve lands for the purpose of benefiting everybody. It may, of

* These densities correspond very closely to those of Auray and Arcachon, the regions of production in France, and are similar to those of production at Tarente (p. 359). The sp. gr. at Burnham (August 15) did not exceed 1.021 at 64° F., at Brightlingsea 1.023 to 1.025 at 65 (August 16). The writer was told by Mr. Newman of Colchester that the Colne waters during the early spring months are perceptibly freshened.

† Philpots' "Oysters, and all about them," London, 1892, p. 366. The price of Colchester seed is here recorded as $1.50 per "tub" (20 gallons) in 1859, and about $2 in 1885. The price at present is about $10 per bushel.

‡ This view appears to be, with limitation, that of Prof. Huxley. Cf. Eng. Ill. Mag., Nov., 1882, article on Oysters and the Oyster Question.

course, be possible that the next season, through favorable conditions, will prove a "spatting" one, although it must be admitted that the chances are decidedly adverse.

When exceptionally favorable seasons can not be depended upon, the means for securing spat suggested by continental experience have been to maintain rigidly a permanent stock of natural spawning oysters. Following this course of regeneration, the spawning-grounds of Auray and Arcachon have developed surprising regularity in spatting seasons, a result which could hardly have followed had the natural supplies been exhausted and had the culturist waited for the advent of favorable years.* (Cf. p. 404.)

To obtain seed oysters in the Thames estuary by artificial processes has been aimed at by many culturists; and the high price of native seed has ever been a great incentive. All experiments, however, have proven unsuccessful. Tiles placed in continental methods on the Whitstable flats were shown to be scarcely more fruitful than a bottom of shells or gravel, a result not unaccounted for when we consider the normal absence of natural spawning beds in the neighborhood and the comparative barrenness of neighboring oysters when constantly cultivated.† The process in use in nearly all the English localities is accordingly little more than the shelling of the ground during the spring, in the manner usual in Long Island waters of the United States. As will be seen in the discussion of the industrial processes, this operation pays for itself by adding to the cultural capacity of the ground, even granting that no seed oysters are obtained. In the event of a favorable season, the shell collection is as apt to be "smothered" with spat, as would be the more costly kinds. Thrift in this matter can not, however, be regarded as British, as tile-collectors, it will be remembered, are only employed on the continent, where at particular points the annual set is sufficiently heavy to make their use profitable.

In artificial production the goal of all English culturists has been the cosmopolitan one, to rear in a reservoir pond a large percentage of the two or three millions of embryos set free by each spawning oyster. The profits of a success in such a venture, even for a season, in view of the price of native seed, would be so great that company after company has been organized for the purpose of artificial culture. Costly ponds have been prepared, varying in size from square yards to acres, with almost every condition of bottom, density of water, kinds of collectors, number of contained spawning oysters, and devices (including steam power) for water aëration. In one instance (Hayling Island) may be mentioned an ingenious device for changing the water in the breeding pond, a device which allowed the surface water to be withdrawn at night and the bottom water during bright sunlight, when the young were supposed (upon what exact evidence the writer is unable to learn) to seek the surface. The difficulties that have stood in the way of the success of these enterprises appear to have included excessive saltness of water, sediment accumulations, and malaëration caused in the main by the restricted area of the basin, which has resulted in fouling the water by the death and decomposition of the inmates of the pond. With these evils there has often been a general mismanagement financially. During the first

* In regard to regulation, see Huxley, *loc. cit.*, latter part of article.

† Hoek, *loc. cit*, p. 481.

season, in many cases, the cleanliness of the new-made ponds has given the experiments almost a phenomenal success.

Permanent successes in pond culture have never occurred, and in the present connection it would scarcely seem necessary to consider in detail the experiments carried on at various times by the establishments at Reculvers, Emsworth, North and South Hayling, Braiding, Newton, and Poole.

To be able to buy seed oysters cheaply in France has obviously been of far greater importance to the English culturist than all of his experiments at production, and as an alternative has no doubt caused this branch of the industry to be neglected. Young seeds transplanted to English waters become, after three years of growth, identical in shape and taste with English natives,* and are often sold both by culturists and dealers at the prices of the best grade of natives. The profit in such a case is so great that it becomes of great commercial advantage for unscrupulous culturists or companies to keep profoundly secret the origin of its seed oysters as well as their relations with the buying agents in France and the selling agents in London.

CONCESSIONS.

The English oyster-grounds may be roughly classed as public, private, or concessional. The public grounds include all natural beds and unoccupied portions of the foreshore. They may be worked within stated months, and as their limits and favorable points are well known to the fishermen, they are in general exhaustively dredged. Private grounds extending under water have practically the same vested rights as farming land; but their use in oyster-culture, by reason probably of expense, appears to be limited.

By far the greater part of the English cultivated grounds are held directly from Parliament by a fishery order obtained by petition through the Board of Trade. By this means a company or individuals may obtain on long lease at almost nominal rental a tract of the foreshore, but with the condition that it must be cultivated, or, on an adverse report of an inspector of fisheries, revert to the state. This stipulation has in many instances proven a very desirable one, since it has allowed the lands to become used by a second tenant if a former one was remiss in its cultivation. Culturists accordingly are subject to the criticism of their neighbors, and on their complaint to an investigation by the Board of Trade, whose inspectors determine and report whether the concession, altogether or in part, is maintaining its usefulness to the general public. This feeling in regard to taking away property from the public fisheries, sharpened by much adverse criticism when the matter of fishery orders was being discussed, has no doubt had its weight in rendering the process of obtaining a concession a long and somewhat troublesome one.

* This was stated to the writer by one of the most influential culturists at Whitstable. The circular mark showing the original attachments of French seed to the tile becomes in many instances obliterated; its absence can not therefore be regarded as an infallible test.

It is contended, however, by the fishermen that a fishery order is so difficult to obtain that it can be utilized only by syndicates, or culturists of the wealthiest class. The first step in obtaining a concession, as stated in the act of 1868,* is to show that the property in question is unoccupied and is not held under previous grants. This process naturally becomes difficult in a locality long known to have been of cultural value, and may render it first necessary to carry through a petition which reduces the size of an unutilized neighboring grant,† a result, however, not easily attained, as the defendant is apt to be a wealthy and litigious corporation. Monopoly in the management of an oyster-ground occasionally ensues, and the land appears to accumulate in the hands of the wealthiest culturists. The famous Kentish flats of Whitstable are held by only a few corporations; the Colchester grounds by a single one.

In this regard it is interesting to contrast the Dutch system of competitive land-rental with short leases, where the state reaps the profit of the high rental and where sharp competition among many culturists tends to reduce the market price of the product.

* The sea fisheries act (July 13, 1868) indicates the course to be pursued in obtaining a foreshore concession—one over whose area the tenant is given right to dredge, plant, and remove oysters at any and all times during an extended period (as long as sixty years), provided that its usefulness to the public is guaranteed. By instructions from the Board of Trade, applicants must "cause printed copies of the draft of the order as proposed by them" to be circulated to owners, lessees, occupiers, and neighbors of the portion of the foreshore to which their application relates. During a month thereafter the Board of Trade is to receive written objections to the grant of the petitioners. The matter then passes into the hands of an inspector of fisheries who shall weigh evidence for and against the application, and, if necessary for this purpose, may hold a sitting in a locality convenient to the property in question. His written report, for consideration of the Board of Trade, approves of, deems inadvisable, or sets conditions upon the application. The Board of Trade is now empowered to make out the fishery order, define terms and duration, costs in all matters to be defrayed by petitioners. The order is now approved by act of Parliament, if it is found in no way conflicting with the useful rights of older acts, charters, or prescriptions. A more speedy course is afforded by the law of 1877, whereby a tract of 5 acres (twenty-one years' duration) may be secured directly by consent of Her Majesty in Council. Provision is in every case made for continuing to secure the benefits to the public of these conceded lands, through annual reports of the fisheries inspectors to be laid before Parliament.

The act of 1868 provided, furthermore, for protecting the private oyster-grounds from trespass. It must be proven that the property in question was removed from the plaintiff's grounds. Staking and buoying of a concession is made obligatory, and it is provided that printed copies of a fishery order must be kept on sale in a convenient locality.

Besides the general restriction of oyster dredging during the summer months, it is provided by the law of August 10, 1877, that deep-sea oysters are forbidden to be bought or sold between the 15th of June and the 4th of August, unless for purposes of cultivation. The Board of Trade is empowered to reserve banks for the period of a year, with right of yearly extension, for purposes of regeneration. The restriction of the general sale of oysters (act of 1877) during the summer (May 14 to August 4) appears to have been commonly disregarded to the detriment of all spawning regions. Firm action, however, in this matter was undertaken during the summer of 1892, by the Fishmongers' Company. A number of prosecutions as test cases were instituted and convictions were secured. With this precedent the company, it is hoped, will be enabled during the coming summer to entirely close the sale of oysters and establish a season of much needed tranquillity on the spawning-grounds.

† Anson and Willett, prize essay of the International Fisheries' Exhibition, Clowes, London, 1884, p. 102–111.

CULTURAL PROCESSES.

Perhaps there would be no better way of understanding the character of the English oyster industry, both in its management and in its processes, than by examining briefly a typical oyster company, as for example that of Whitstable. The Whitstable Company is an oyster syndicate of the most powerful type, exceptional in its antiquity and in its closely coöperative character. It grew up about a century ago, and in 1793 secured by royal charter about 3 miles of the best oyster-fattening grounds of the Kentish flats. Its organization is an interesting one; its membership is hereditary, and was formerly the birthright of every son of a "freeman" of the company. The number of members, however, became finally so great* that for convenience as well as for economy in management, a restriction was made admitting to the company only the eldest sons of freemen. Every member has a voice in all matters of management. A small evening parliament is held monthly in the assembly room of the building overlooking the Whitstable grounds (Pl. LXXXVIII, Fig. 1), and all matters of management, including buying and selling, are here very generally discussed. The members constitute a clan, with two or three family names predominating, which has come to regard outsiders with commercial suspicion, and has long been extremely reticent in regard to the ways and means of management. Each member of the company is entitled to a mutual dividend of profits, and to be employed with stated wages as often as his turn may come. The "stints" in the necessary cultural operations of the grounds are known and assigned to members beforehand, and "a bell is carried round and rung every morning to rouse the dredgers whose turn it is for duty."† An idea may be obtained of the extent of the Whitstable Company when we consider its small army of employés, its fleet of sixty dredging boats (Pl. LXXXVII, Fig. 1), and its invested capital in cultivated oysters valued at $1,000,000. The annual sales of the company are estimated at from $800,000 to $1,000,000.

In an industry like that of the Whitstable Company it is quite evident that the amount of natural set upon the cultivated grounds must be an almost inappreciable portion of the seed oysters that are there cultivated. It is said, in fact, that all of the seed that can annually be purchased on the 30 square miles of Kentish flats, or in all other natural oyster-producing regions of Britain, could together form but a small item in the annual purchases of the company. So favorable, though, are the conditions for growing and fattening oysters at Whitstable that the exact origin of seed oysters seems a matter of minor importance; at the end of three years the seed purchased economically from Auray has become in every appreciable regard an "English native."

The processes of growing and fattening oysters are not widely different from those of Connecticut; the methods of culture employed by the French or Dutch have certainly not been followed.

Seed oysters ("brood" oysters) are usually purchased in the early spring, when they are taken to a portion of the grounds where not more than a fathom of water is retained at low tide, and are strewn thickly over the bottom. There seems to be no danger at Whitstable of planting too thickly, there being apparently no dearth of food organisms, and the dredgers believe that "oysters fish (fatten) better when they are thick laid." Dangers from mud or sand do not occur. The bottom is smooth

* In 1876 there were 400 members.

† See Philpots', *loc. cit.*, p. 364, for a very interesting discussion of the Whitstable fishery.

and hard, as it has been for ages regularly shelled, dredged over, and cleaned. There are many men and boats employed by the Whitstable Company, and it is usually arranged so that the detachment of dredgers shall spend half the week in "catching" the oysters for market and the remaining half in "cultivating" the grounds. Cultivation consists in dredging over the grounds with a view to dislodging weeds and sediment, to keeping the ground clear and level, and to capturing the oyster enemies. The reshelling of ground is usually practiced during the early spring. Apparently no attempts are made, as on the continent, to increase the extent of cultivable lands by inclosing, as might easily be done, small areas near the line of low water. As seen on Pl. LXXXVII, Fig. 1, a large portion of the shore line is exposed, which in France or Holland would be far too great in value to lie fallow.

It is obvious that case culture (p. 386) would be expensive and meaningless in a region like that of Whitstable, where danger from mud or sand, or even enemies, appears to be at a minimum. The only device for this kind of culture which might perhaps be practical would be to extend wire gauze a few inches from the bottom to permit an additional tier of oysters to be reared. During a second or third season the only additional process is the transfer of oysters into deeper water—*i. e.*, 2 fathoms—there to remain until they have become of marketable size. The larger oysters appear to be less endangered by sediment deposits and thrive even where the ground is soft enough to allow the weight of the oyster to sink it below the surface of the mud. The dredgers firmly believe that under these conditions the oyster has to some extent the power of gradually regaining the surface, and cite as proof of this fact that oysters in a given place may be dredged in greater quantity after several days of rest have been given them. This power on the part of the oyster has been questioned by several zoölogists, but the writer regards the proof furnished by the parks of Cancale and the Marennes as sufficiently affirmative to place the matter beyond question. Oysters dredged for market are finally brought to the warehouse of the company, and while awaiting shipment are classified, placed in loose baskets of netting in concreted tanks or "pits" (seen in Pl. LXXXVIII, Fig. 2) fed by tidal water.* These pits are often located for shelter in the warehouse, forming, in fact, a kind of masoned cellar, whose compartments of about 20 feet square may be refilled at high tide and retain 8 or 10 feet of water. By this method of storage a large number of oysters may be kept in safety for immediate demands, and serve as a reserve supply in case stormy weather prevents dredging. Pits of this character are not regarded as of value at Whitstable, either for fattening or *dégorgement*.†

Oyster-culture in England generally varies but little in methods from that of Whitstable; other localities, therefore, need be but little commented upon. At Faversham, westward, and at Herne Bay, eastward of Whitstable, sediment deposit and invasions of mud, and at the latter place shiftings of sand also, have been of considerable annoyance. The remedy has been continual dredging of the grounds together with judicious shelling or macadamizing of the bottom at certain points. Weeds have been carefully dredged out as a means of keeping the ground clear and allowing the tides to wash off the depositing sediment. In regions where spat is expected to occur with some regularity, the greatest care is taken, by reshelling and clearing the bottom, to assure the greatest chance of a successful set. This character of bottom is often

* In the pits of the Whitstable Companies' warehouse the water (August 13) at 68° F. was of sp. gr. 1.0245. The temperature was here higher by 5° than the tidal water immediately without.

† U. S. F. C. Bull., 1890, p. 380.

secured in the rivers Blackwater, Crouch, and Colne (below Colchester) by a regular process of harrowing the bottom during the beginning of the spring. By this means the loose sediment accumulating during the winter is broken up and carried off by the tide. For this operation a harrow is prepared whose teeth, 2 or 3 inches in length, are of iron, bent slightly forward at the tips. When in use it is carefully arranged so that the teeth may not break through the crust which was formed by the shelling processes of former years; this is prevented by adjusting the length of the harrow rope from the dredging vessel, and the behavior of the harrow, like that of a dredge, is readily determined by the "feeling" of the rope.

Along these rivers tidal pits dug out mainly in open ground are very frequently employed. Their use is principally for storage during the winter and early spring, as it is said that serious losses are then caused by the freshening of the rivers at low tide, "when the oysters are so weakened that they become particularly sensitive to frosting."* In regions where the water is considerably salter, as at Falmouth (60° F., 1.0265, August 10), pits are not generally employed. In some instances they are used for providing temporary shelter.

A brief notice may be given of the commoner varieties of oysters of the English market. The highest grade is the "Native," Whitstable, Faversham, Brightlingsea (Colchester), a small oyster measuring $2\frac{3}{4}$ by $2\frac{1}{2}$ inches, with a smooth, thin, pearly shell, having a firm, smooth margin, valve outline stoutly crescentic, animal well "fished" (fattened), white; retail price about 4*d.* apiece. The Burnham native, "Button oyster," or "Tom Thumb" is highly esteemed; it is remarkably small, stout, and heavy, and appears to be of extremely slow growth; individuals at least 15 years old have been noted. The majority marketed are of undoubted French origin, having been for a longer or shorter time laid down in English waters. These are comparatively low in price, and are known under various trade names—Royal, Victoria, Seconds, Arcachons, Aurays—usually to be recognized by their shape and by the circular mark upon the shell, often with adherent cement, showing where the seed oyster was formerly attached to a collector. This, too, is one of the marks of the small oysters from Ostend. Large, rough-shelled North Sea oysters are not uncommon. The cheapest grades are the American and Portuguese. Of the former, those that the writer has seen appear to have been of southern origin, similar to those largely planted in the waters of Long Island Sound; when laid down in English waters they grow rapidly and become exceedingly "well fished"; their color, however, appears to change from white to leaden gray, and the taste becomes metallic, resembling that of the Portuguese oyster. The American species does not appear to spawn in the English waters, although some specimens examined by the writer at Whitstable were with well-developed ovaries and appeared to be almost in spawning condition. The price of the best relaid American oysters is about 40 shillings per 1,000. Portuguese oysters retail at about half of this price. They grow very rapidly, an instance of a growth of 4 inches in two years being recorded. Their spawning in the Medway, at Sharfleet, has been observed.†

The oyster industry in England, it will be seen, is established on a different footing from that on the Continent. It has developed characteristic features, owing, in a large measure, to the difficulty with which any fishery rights may be taken from the people. Not that there has been a lack of interest on the part of people or

* This was stated by Mr. Newman, Colchester, August 16, 1892. † Philpots, *loc. cit.*, p. 355.

Parliament in the practical question of regenerating the industry and of fostering oyster-culture. The public has, even to a remarkable degree, been extravagant in supporting financially almost every experiment at artificial culture; this interest being doubtless caused by the increasing price of oysters, and not a little influenced by the proofs of the successes of continental culturists, which were notably shown at the International Fisheries Exhibition held in London in 1883. Scientists, foremost among whom was Prof. Huxley, became greatly interested in the biological side of the oyster problem and were always willing to offer their counsel. Parliament in important sittings discussed at length the matter of fishery legislation*, published reports on foreign methods of culture, and investigated with the greatest minuteness and care, by select committee, the causes of failure of spat and of the decadence of the industry.

But with all these cares there was ever in the way an obstacle which people and Parliament, in spite of the temporizing experiments of the past quarter of a century, have been unable to successfully evade. To what degree would it be wise on the part of government to absolutely restrict the public fishery in preserving public lands? This question is clearly one that comes directly in conflict with the ancient rights of individuals in the public fisheries. To effect decided changes, perhaps even minor ones, in this fishery system, would be an absolute measure which touches the liberties of the British subject, and would be opposed just as even the concessions that have been granted for cultural purposes are seriously criticised as reducing the public grounds and robbing the dredger of ancestral rights. Parliament has endeavored to move conservatively, and has itself considered and granted by special act all of the newer concessions. Its action, however, appears to be more and more regulated by the advisory reports of the fishery inspectors of the Board of Trade, a board which thus becomes directly intermediate between Parliament and people. On the part of the fishermen the position of the ancient Fishmongers' Company is one of great influence. This company, as is well known, does the most beneficial and disinterested work in assuring the character of the fish supply of London, and in the efforts to regenerate the oyster fishery its action in assisting the government is wise and exceedingly liberal. Its recent position in restricting the sale of oysters during the summer has already been noted (p. 397).

Conservatism on the part of the government as to public rights in natural oyster regions has given the dredgers every possible opportunity to carry on their industry unrestrictedly, excepting of course during the summer months. If no more stringent methods have been undertaken, it has been partly because there have been no pressing complaints on the part of culturists for the betterment of the industry. To purchase seed oysters raised artificially on the Continent has been an alternative not distasteful to Auray or Zeeland, not lacking in profit to the English culturist, and giving the British market an abundant supply of oysters, but a supply for whose expensive production the public must pay. The dredger is gradually finding that his ancestral right to the public grounds, which he has struggled to retain, and which government has generously allowed (giving him the benefit of the doubt as to whether its preservation would not in the end prove more valuable), is not after all of great value in the absence of natural oysters, and that all the profits in the industry must belong to capitalists and companies who deal in foreign oysters, and in whose employ he can himself most profitably make a living.

* Report of Select Committee (House of Commons), July 7, 1876.

CONCLUSION.

A summary has now been given of the present character of the oyster industry in Europe. The intention has been, first, to give a glimpse of the actual processes of oyster-culture, and, second, to show in a general way the influence exerted upon the industry by governmental concessions or restrictions. Together with these a number of questions relating to the living conditions of the oyster have been discussed, and as the interest connected with them may, in several instances, be more than theoretical, they may be briefly summarized. It would appear, for example—

1. That the degree of density of the water is one of the most important factors influencing the spawning and fattening of the oyster. This degree of salinity, which represents the *optimum* of spawning conditions, has been found in all countries to be delicately poised. The density of the water recorded in the best spawning-grounds of the French coast is practically that of the spawning-grounds of Italy and of northern Europe. It may be stated that the specific gravity of the water in regions of maximum production throughout Europe appears to be uniform at about 1.023* in the case of the "flat" oyster (*Ostrea edulis*), and at about 1.021 in the case of the Portuguese species (*Ostrea angulata*). The influence of warmth is not to be underestimated in regard to the time and degree of spawning; it is meant, however, that in one zone or locality, *i. e.*, bay or estuary, where the water density is favorable, there is a more decided tendency to a fall of spat than in a locality of corresponding temperature immediately neighboring, where density may differ by only a few thousandths (*e. g.* 0.002) of a degree.

2. That the amount of spat occurring annually in a region appears to be directly in proportion to the number of spawning oysters in that region. This is by no means a novel suggestion; it is one, however, that has been repeatedly impressed upon the writer. The older idea, it will be remembered, is that banks can never be exhausted, on the ground that the few oysters left by the dredgers will, by the annual spawning of several millions of young, cause a very rapid regeneration. That the banks regenerate is true,† but the process is shown to be slow, and beset with many difficulties. The older proposition is, in brief, untenable, because, as Möbius pointed out,‡ the percentage of loss of oyster fry is apparently a normal factor (under natural conditions). It may be seen, as an illustration, that the immense annual spawning product of one oyster may in time give rise to no more than two adults; and from a practical standpoint, accordingly, the large number of eggs produced by a single oyster would make little difference in the growth of the natural bed. It should be noted that only in those places in Europe where the natural bulk of spawning oysters is actually maintained does a great quantity of spat occur regularly; also that where the number of spawning oysters is equal the percentage of spat will be notably greater if the spawning oysters are little disturbed.§

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* The observations were made at nearly corresponding seasons.

† Möbius, *loc. cit.*, p. 77. ‡ Möbius, *loc. cit.*, p. 79. § Cf. Hoek., *loc. cit.*, p. 481.

3. That the amount of oyster food appears to be notably characteristic of a locality whose normal food value is represented by conditions of warmth, density, and richness in the organic and inorganic salts, which serve to rapidly generate the oyster-food organisms. Should this natural food value of a locality be a high one, culture has demonstrated empirically that the number of oysters that may be reared is exceedingly great. It would appear that the number of oysters to be fattened is directly proportioned to the food normal of the locality and to the volume of water which passes over the bed. The actual size of a natural oyster bed is limited by other reasons than that of failure of the food supply in the neighborhood.

The study of the management of the natural oyster-grounds of Europe has been a suggestive one, not as much in regard to attempts made to render them more fertile and more serviceable in directly supplying the markets, but in their indirect yet important bearing upon the production of seed in neighboring areas. This system of stated oyster reserve has been the key to the success achieved by the French and Dutch industries, and has alone rendered it possible for these two countries to supply the entire seed market of Europe.

To obtain seed oysters by collectors is shown to be possible only when a regular yearly fall of spat is thus assured. Proximity to a large stock of spawning oysters is one of the imperative conditions of artificial production, a condition that has been too often lost sight of in experiments made along the Atlantic coast of the United States. Collectors in Europe are placed on no river bank or sunk in no stream save where the culturist is fairly sure of a set that will be at least profitable.

If experiments in artificial production are to be made in the United States the suggestion given by European oyster-culture is to secure for the purpose a particular part of beach near the line of low water, where spat has been found to regularly occur. If a trial demonstrates that the locality is favorable, the European culturist would then gradually and carefully expend his money in the purchase or preparation of a more extended area for collecting, and would study to provide the most suitable form of collector.

It may be said, in passing, that experience has found no more economical collector than the tile. This has proven especially valuable in adapting itself to the needs of the locality, may be spread singly over hard beaches, where there is no danger of sediment, and may in muddy regions be arranged in banks or *champignons*.

There can be no doubt that artificial production would succeed in American waters. The question is the practical one, whether it would, on an extended scale, be less costly than the price of natural seed. This can only be determined by experiments in a favorable locality.

Artificial production, it will be remembered, is largely carried on near the line of low water. Open tidal ponds, utilizing for this purpose a higher zone of the shore, have as yet never given the best results. In closed tidal ponds the small water volume has never been successfully aërated for the needs of production: the use of a closed lake whose large size shall insure aëration naturally may prove permanently successful and should not be lost sight of.*

* U. S. F. C. Bull., 1890, p. 372.

The phase of European oyster-culture that has as yet no equivalent with us at home is that of the extreme value of land at particular points. Competition in these favored localities has added in various ways to the area of production and culture. Land is made by the macadamizing of soft and useless tracts; a higher zone of the beach is utilized by tidal inclosures; wire cases raise the oyster from the muddy bottom and protect it from its enemies; and in Italy *vertical* culture is even resorted to in a very extraordinary way. (See page 360.)

The general need in the United States for area in which to extend oyster-culture can hardly be regarded as immediate. At points, however, where the local cultural conditions are exceedingly favorable to rapid growth or fattening, it would seem a practical measure to bring into cultivation extended shore strips near the zone of low-water mark by the use of tidal parks of the least costly type.* In regions where softness of bottom and richness in the oyster's feeding conditions are noteworthy, the use of case culture is most strongly to be recommended, from its practical value. Culture in *claires* is easily understood;† its results in giving a special and delicate flavor to the oyster should commend it to culturists.

Significant, although perhaps not strictly logical, deductions may be drawn as to the way in which different action on the part of different governments has affected the prosperity of oyster-culture; the granting of concessions, the terms of tenure, the preserving of the natural grounds, interference or non-interference, have undoubtedly exerted much influence in developing or retarding the industry, although it is clearly to be understood that only the most general inferences can be drawn on account of altered conditions, *e. g.*, of climate. In the accompanying table (p. 406) a brief contrast has been attempted. It will be seen that in those countries alone where government has absolutely preserved supplies of spawning oysters does seed-culture flourish. The permanent closure of a small natural oyster-bearing area has apparently done what has not been done by a close season of the r-less months. The latter course, as argued by Prof. Huxley,‡ does not prevent the dredgers from exhausting the banks before the spawning seasons begins; and Prof. Hubrecht§ notes that for similar reasons the close seasons might equally well be during the winter as during the summer.

That absolute reservation of oyster-bearing land will have an immediate and important influence upon the production of seed in neighboring areas is a proposition which European experience seems to demonstrate; and the writer would suggest, as in his former report, that the matter of reservation seems far more pertinent to the needs of the American industry than any attempts at artificial production. Nor would the reservation of such a tract be an impracticable matter, at any rate as an experiment, and if its importance could be shown in a region where the seed industry has been prosperous and is now depleted, a government experimental control might give place to permanent measures on the part of individual State, or of local authority. If the importance of this question could, by experiment, be demonstrated clearly and practically, the culturists themselves would become the most actively interested in the matter. *The normal quantity of spat is in direct proportion to the number of spawning oysters in the neighborhood*, and, although this fact may be clearly recognized, the

* U. S. F. C. Bull., 1890, p. 376. † *Loc. cit.*, p. 376. ‡ Lecture on the Oyster, May, 1884.
§ Int. Fish. Expos., Prize Essay, 1884, in Philpots, *loc. cit.*, p. 702.

culturist must in general, for commercial reasons, remove and sell a large part of his stock, leaving in total remainder an amount whose spat product is an inadequate one. Authority can not forbid the culturist to remove the oysters before the spawning season, and political economy can not expect that one man will purposely leave a large stock of oysters to spawn for the common good of the neighborhood. Reservation is clearly a governmental duty, whether State or local. The matter is not a new one, and the condensed experience of Europe merely emphasizes what, with various modifications as to tenure, time, and degree, the authorities on this subject in the United States have already advised.

Among the European systems of rental of state lands, the carefully devised method of Holland is worthy of consideration, especially as the matter of rental with us will become of greater importance as demand for cultural property increases. State policy in Holland has not hesitated to give short leases at competitive prices, on the ground that valuable land should not be continued in the hands of one who does not pay for it a just rental, and that the balance established by competition is apt to be fairest in the end to all interested parties, state, culturists, and public at large.

In conclusion the author must gratefully acknowledge the generous assistance of those whom he was obliged to consult during his visits of inquiry. For his notes on the German industry he is especially indebted to Prof. Karl Möbius, of Berlin, to Baurath Weinreich and Herr E. Storm, of Husum, and to the brothers Feddersen, of Schleswig. In Holland he must acknowledge the personal kindnesses of Prof. Hoek at the Helder, Baron Groeninx van Zoelen, Mr. J. Ochtmann, and the inspector of the Dutch fisheries, Mr. C. J. Bottemanne, at Bergen-op-Zoom. At Ostend he had the opportunity to meet M. Hamman, secretary of the Fisheries Board, and was very kindly presented to a number of culturists. To Cav. Domenico Pollio, of Pozzuoli, and to Sr. S. Milosa, at Fusaro, he must also express his indebtedness. In England he was received at the Board of Trade by Mr. A. P. Berrington and Mr. W. Fryer, and at the Fishmongers' Company by Mr. T. Wrench Towse, and was by the courtesy of these gentlemen introduced at the various centers of oyster-culture. He is also indebted to Capt. G. L. Austin and to Capt. A. Anderson at Whitstable, to Mr. A. C. Wanklyn and Mr. J. Newman at Colchester, and to Mr. J. Smith at Burnham.

SUMMARY OF EUROPEAN SYSTEM.

A. Of Management of Natural Oyster-Grounds:

All are property of the state.

(*a*) Dredged by licensed fishers with closed season of the summer months: England, Italy, Spain and Portugal, Germany.

(*b*) Dredged exceptionally or never; beds to furnish spat for cultivated areas: Holland, France, Italy.

(It is to be noted that in countries where the natural beds are absolutely closed to the public the seed-oyster industry is most prosperous, supplies local wants, and furnishes even in great part the neighboring countries). In the case of Italy the Mare Piccolo, the only region of extensive production, has virtually this restricted character.

B. Of Cultural Methods:

(*a*) Production:

(1) No seed oysters produced: Belgium.

(2) Seed oysters produced naturally on natural oyster banks, no cultural devices, entire industry feeds on natural annual surplus of oyster banks: Germany, Portugal, Spain.

(3) Seed oysters taken with collectors.

(1*a*) On open shore near low-tide mark:
Tiles in single layer: Holland.
Tiles in banks, bouquet or champignon, wooden plateaux: France.

(2*a*) In open deeper water:
Floating collectors, fascine: Italy.
Shell cultch: England; in part, Holland.

(3*a*) In closed ponds, small, never with permanent success.
In closed ponds, large: France (?), U. S. F. C. Bull., 1890, p. 372.

(*b*) Élevage:

(1) No artificial cultural processes, no transplanting: Germany.

(2) Oysters planted along suitable foreshore: England; in part, Holland, Portugal.

(3) Oysters reared during first year in wire-gauze cases, afterward reared entirely in tidal inclosures: France, Holland, Belgium, Spain.

(4) Oysters reared to marketable size attached to collector, oyster-bearing ropes: Italy.

(5) Special processes:
Flavoring: France, Belgium, England; with color, France (Ostend?).
Dégorgement: France.
Special storage in tidal "pits" or ponds: England, Belgium (Germany).

(C) Of Granting Concessions of Cultural Lands:

(1) Cultural property in general private, no government (aids or) restrictions: Belgium, (Ostend).

(2) Cultural property governmental.

(*a*) Concessions of freeshore rarely if ever granted for purposes of culture, extreme restrictions, long leasehold: Germany.

(*b*) Concessions of, granted on long lease, nominal rental, by special governmental act, obtained with more or less delay and difficulty: England.

(*c*) Concessions of, obtainable by direct petition of fisherman or culturist by aid of a local government official, prompt and direct, no cultural companies: France.

(*d*) Concessions of similar, from local government, with subleaseholders: Italy.

(*e*) Concessions of short leasehold, competitive rental: Holland.

FIG. 1. TARENTE, ITALY. GENERAL VIEW OF MARE PICCOLO, TAKEN FROM THE CITY, LOOKING TOWARD THE MARINA DEL CITRELLO, SHOWING EXPOSED ENDS OF OYSTER STAKES.

The skiff load of oyster-bearing ropes is about to be put in place. (Page 359.)

FIG. 2. FUSARO, ITALY. A FASCINE WITHDRAWN FROM THE LAKE TO EXAMINE THE CHARACTER OF THE SET.

Oyster stakes to which fascines are attached may be noted in front of the Pavilion Reale. (Page 364.)

FIG. 1. TARENTE, ITALY. THE PREPARATION OF THE OYSTER ROPES FOR ÉLEVAGE.

Workmen are engaged in chopping up the fascines into oyster-bearing twigs. These, as seen in the basket in the foreground, are to be woven, or rather spliced, between the strands of the rope seen in the lower right-hand corner. In the middle distance behind the workers are embankments of fascines. (Page 362.)

FIG. 2. TARENTE, ITALY. MUSSEL-BEARING ROPES.

These may be taken to represent the appearance of those woven with the oyster-bearing twigs of Fig. 1. (Page 362.)

FIG. 1. LUCRINE LAKE, ITALY. GENERAL VIEW FROM THE HIGHWAY TO NAPLES, OVERLOOKING THE EASTERN END OF THE LAKE.

The foot of Monte Nuova forms the background at the right. The stakes at the left bear collectors and fascines for élevage. The fish runway of straw, seen in the foreground, leads to the sluice gate of the next figure. The location of Lake Avernus, the Acheron of Virgil, is directly behind the atelier shown in background. (Page 365.)

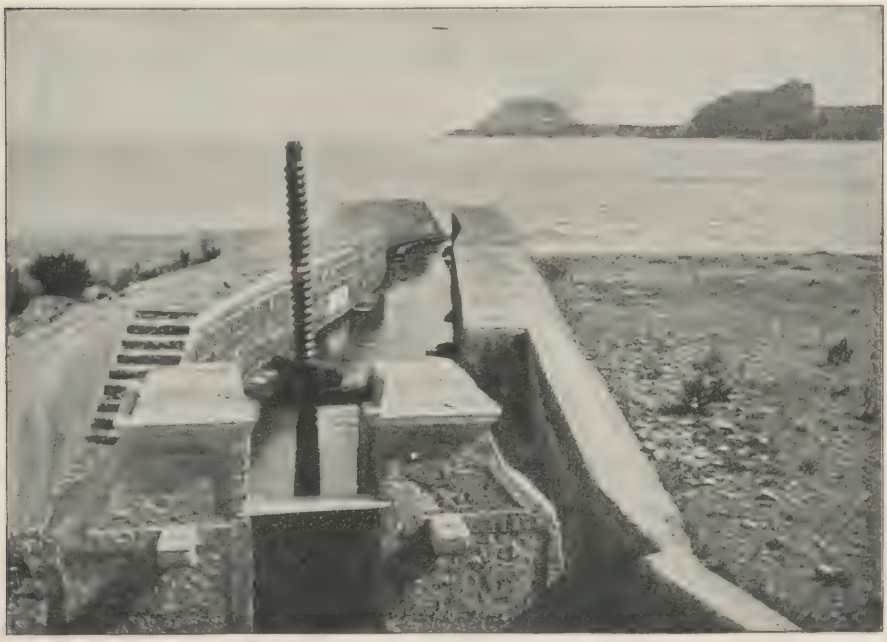

FIG. 2. LUCRINE LAKE, ITALY.

The tidal gate with stone breakwater, as seen from the road to Naples, Cape Miseno in the background. (Page 365.)

FIG. 1. FUSARO, ITALY. ÉLEVAGE OF OYSTERS OF SECOND YEAR; A REARRANGED FASCINE SEEN AS LIFTED FROM THE WATER. (Page 364.)

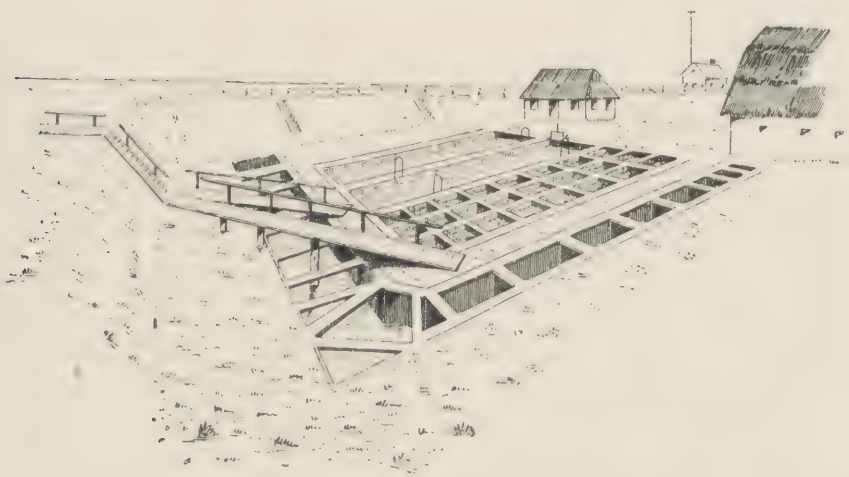

FIG. 2. HUSUM, GERMANY. GOVERNMENT STATION AND OYSTER-STORAGE PONDS.

The bank of the Husum Canal is seen at the left over the marginal dike. Behind the embankment in the background is the reservoir, whose water passes into the main middle storage pond through the water gate seen in front of the house. Thence the water passes into the lateral ponds, thence to the surrounding U-shaped reserve canal, escaping at the left, piercing the dike. From sketch by the writer. (Page 377.)

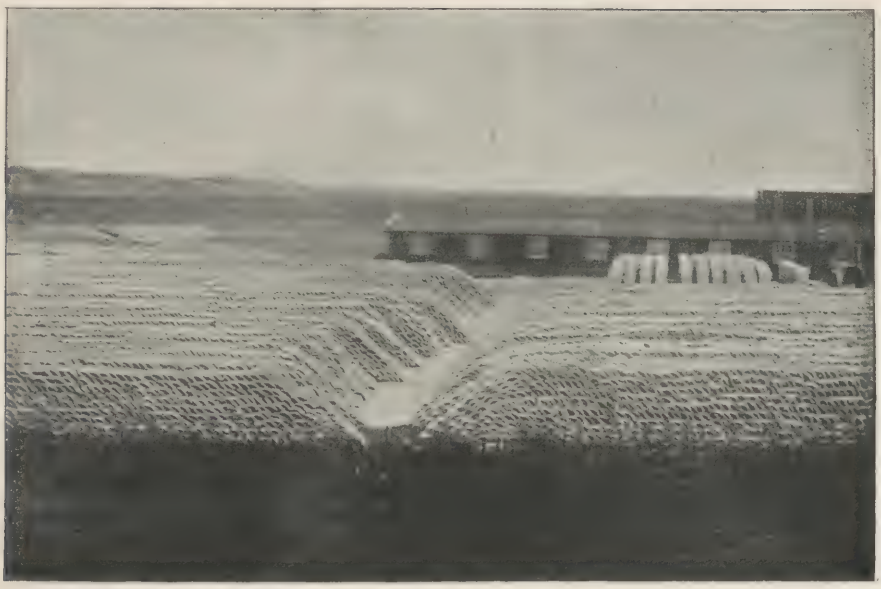

FIG. 1. VIEW OF AN ESTABLISHMENT AT BERGEN-OP-ZOOM, HOLLAND.

The dark foreground is the sloping landward side of the dike. The chalk-covered tiles are arranged ready to take over the dike, and be loaded upon the fishing vessels and transferred to the collecting grounds. The workshops are seen, and at the left over the tiles the margin of a culture pond. This land was formerly a polder. (Page 384.)

FIG. 2. FISHING BOATS RECEIVING CARGO OF TILES FROM THE ESTABLISHMENT SHOWN IN FIG. 1.

A hand railroad is seen bringing the tiles over the crest of the dike. (Page 384.)

FIG. 1. JERSEKE-DAM, HOLLAND. A COLLECTING GROUND AT LOW TIDE.

The tiles have just been arranged in fringing rows. The boundary stakes may be noted. An outcropping corner of the dike forms the background at the right. Property of Baron Grœninx van Zoelen. (Page 384.)

FIG. 2. GOES, HOLLAND. A COLLECTING GROUND AT LOW TIDE.

The sides of the channel seen in the background are fringed with tiles. A corner of a tidal reservoir for storage is in the foreground. Property of Mr. Ochtmann. (Page 383.)

FIG. 1. JERSEKE-DAM, HOLLAND. TIDAL INCLOSURES FOR CULTURE AND FOR WINTER STORAGE OF TILES.

The work people are engaged in cleaning the middle pond for storage of tiles. (Page 384.)

FIG. 2. GOES, HOLLAND. A SERIES OF TIDAL INCLOSURES (PARCS) SKIRTING THE DIKE.

Boundary stakes are indicated at the left. (Page 385.)

FIG. 1. JERSEKE-DAM, HOLLAND. A CULTURAL INCLOSURE OF THE BETTER CLASS, EMPTIED FOR PURPOSE OF CLEANING.

Wire gauze cases for élevage are seen, arranged so as to be two trays deep. Water, to the depth indicated on the brick wall, is renewed once in twenty-four hours. (Page 385.)

FIG. 2. BERGEN-OP-ZOOM, HOLLAND. VIEW OF A REARING POND.

This establishment has been located within the lines of the dikes, which is seen in the background of the picture. Several ponds are arranged similar to the one figured. The margins are of turf; the water depth, renewed at high tide, is about 3 feet, the bottom is clayey loam; the transverse beams are of service in handling and transporting the oysters. The ponds serve to retain the spat-covered tiles during the winter season. Further élevage is carried on (1) by placing the seed (i. e., young separated from tiles) into the wire-gauze cases; (2) by strewing the somewhat larger oysters directly upon the pond bottom. (Page 385.)

FIG. 1. BERGEN-OP-ZOOM, HOLLAND. VIEW FROM THE DIKE ACROSS POLDER LAND NOW IN USE FOR OYSTER PONDS.

The rough pond in the foreground is emptied and filled tidally from the main canal without. The incoming muddy water here deposits a portion of its silt, and thus purified passes into the long, narrow reservoir pond to the right of the center of the picture, also into a similar reservoir pond whose sluice is seen at the left. The water thus reserved and enriched by the growth of food organisms, is daily fed to the larger pond, which indicates at the water surface the position of culture cases. (Page 386.)

FIG. 2. BERGEN-OP-ZOOM, HOLLAND. AN ESTABLISHMENT NEIGHBORING AND SIMILAR TO THE LAST. WORKSHOPS IN THE BACKGROUND WITH RESERVOIR PONDS.

The cultural pond in the middle is traversed by beams which facilitate the transport of oysters to different points of the pond. Tiles about to be put in use for collecting spat are arranged for storage at the right.

FIG. 1. HOLLAND. A NETHERLANDS STEAM OYSTER DREDGE, A SIDE-WHEELER EXTREMELY BROAD OF BEAM (BELONGING TO MR. OCHTMANN, BERGEN-OP-ZOOM).

The figure shows the long windlass of a donkey engine placed amidships, a reel at the stern over which the incoming lines pass, and a high-arm bar which helps to raise and empty the dredge. An example of the ordinary dredge will be seen hanging at the stern. (Page 386.)

FIG. 2. OSTEND, BELGIUM. THE MAIN CANAL WHICH SUPPLIES WATER TO ADJACENT OYSTER RESERVOIRS, AS SEEN AT LOW TIDE.

Locks occur at various points, one of which is seen in the background. From that direction enters the fresher water which serves to reduce the density of the water mass of the canal. The degree of the fall of tide may be seen indicated by the water-line stain on the masonry wall. A sluice gate supplying and draining an adjacent oyster reservoir occurs near where the figure on the bank at the right is standing. (Page 389.)

FIG. 1. OSTEND, BELGIUM. AN OYSTER RESERVOIR (CLAIRE).

The embankment in the background is the side of the canal of Pl. LXXXIV, Fig. 2. The sluice gate from canal is seen immediately to the left of the building. The main pond (p. 389) is the reservoir. Projecting from the water surface in front of the house, the margin of the masonry inclosure where the oysters are placed can just be seen. The water of the reservoir is allowed to pass through this inclosure and escape into the canal without. Park of Messrs. Stichert & Strake.

FIG. 2. OSTEND, BELGIUM. A NEARER VIEW OF ESTABLISHMENT OF FIG. 1, TAKEN FROM THE CORNER OF MASONRY INCLOSURE, WHERE OYSTERS ARE STORED AND FATTENED.

The inclosure is seen divided into masoned partitions and traversed with beams, which are used by attendants in arranging and transferring the oysters. The cog-lifting part of the sluice gate which allows the water to pass from one compartment to another is seen at the right, immediately behind the oyster basket.

FIG. 1. BLANKENBERGHE, BELGIUM. THE OYSTER PITS OF DR. ANSELME VER NIEUWE.

A small reservoir pond is seen in the foreground at the right. The two large compartments are "pits" for storage and fattening. The different sluice gates are indicated; their level allows a depth of about 7 feet of water to be maintained. (Page 391.)

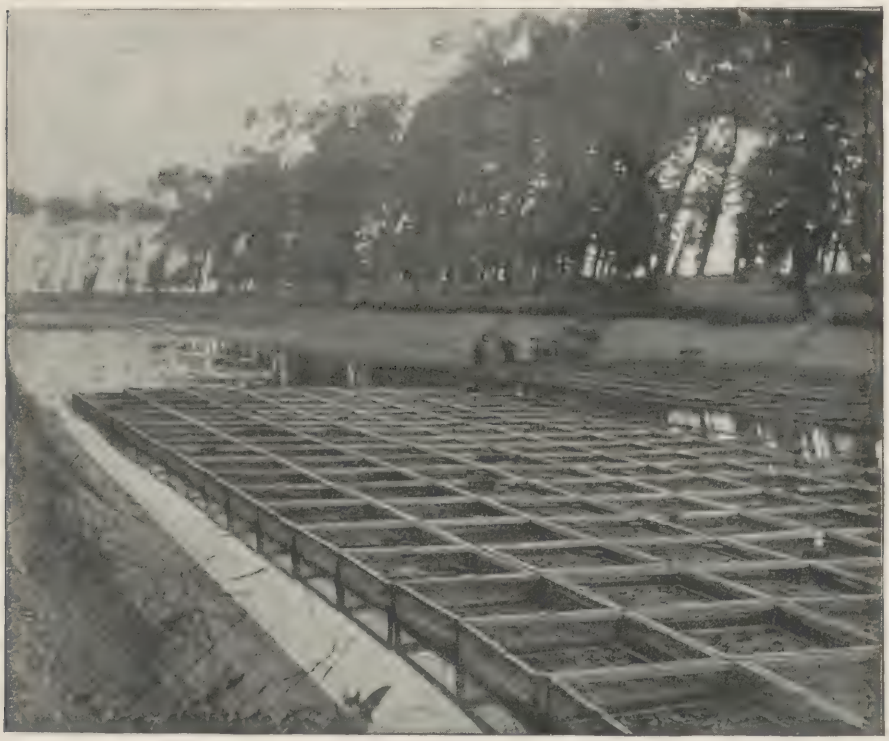

FIG. 2. NIEUPORT, BELGIUM. A CULTURAL POND OF THE ESTABLISHMENT OF MESSRS. MEINESZ & CO.

The water has been partly withdrawn, exposing the wire gauze frames containing tiers of trays of growing oysters. The attendants are engaged in putting in place frames which they have just retarred. The draining canal passes down the middle of the concreted bottom. (Page 391.)

FIG. 1. WHITSTABLE, ENGLAND. GENERAL VIEW OF THE KENTISH FLATS AT LOW TIDE, FROM THE WINDOW OF THE WHITSTABLE COMPANY'S WAREHOUSE.

That the tidal flats are not of soft mud may be inferred from the tilting masts of the dredging vessels. (Page 398.)

FIG. 2. WHITSTABLE ENGLAND. A TYPICAL DREDGING BOAT AT WORK. (Page 400.)

FIG. 1. WHITSTABLE, ENGLAND. WAREHOUSE OF THE WHITSTABLE OYSTER COMPANY, OVERLOOKING THE KENTISH FLATS.

The upper story serves as the meeting room of the freemen of the company. The basement is arranged with "pits" for storage. (Page 398.)

FIG. 2. WHITSTABLE, ENGLAND. THE STORAGE PITS OF THE WHITSTABLE COMPANY; SORTING THE OYSTERS.

The bag-like nets filled with oysters may be attached to the cleats seen in the foreground, and allowed to hang in the water of the pits. (Page 399.)